INVESTIGATING SCIENCE WITH CHILDREN / VOLUME 6

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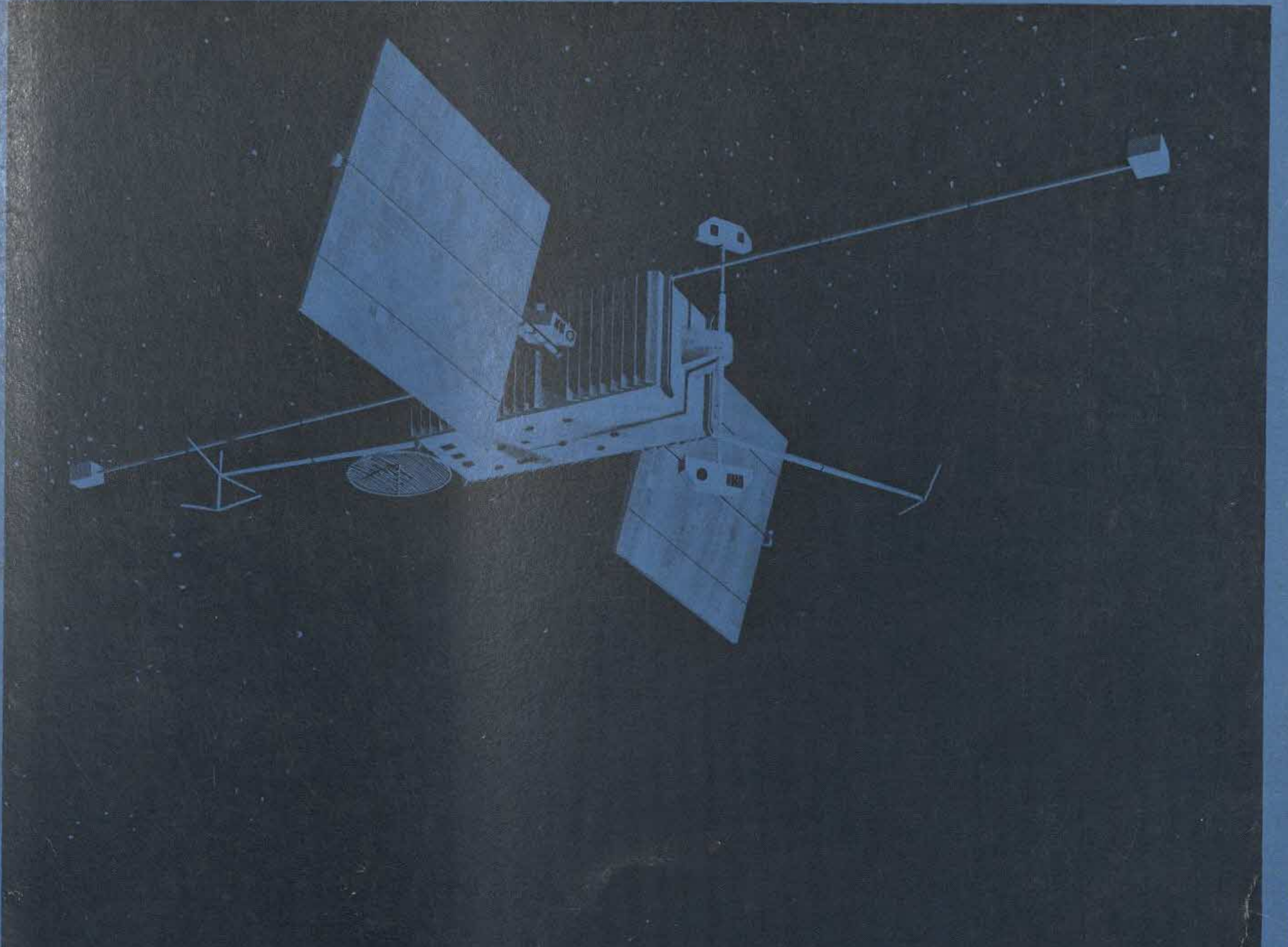
SPACE



National Science Teachers Association

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INVESTIGATING SCIENCE WITH CHILDREN

VOLUME 6

SPACE

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INVESTIGATING SCIENCE WITH CHILDREN SERIES

Volume 1 LIVING THINGS

Volume 2 THE EARTH

Volume 3 ATOMS AND MOLECULES

Volume 4 MOTION

Volume 5 ENERGY IN WAVES

Volume 6 SPACE

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The National Science Teachers Association is a department of the National Education Association (NEA) and an affiliate of the American Association for the Advancement of Science (AAAS).

About the cover: The Orbiting Geophysical Observatory (OGO), a satellite designed to collect geophysical data while circling the Earth, is symbolic of the many types of spacecraft man uses to learn about the universe.

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About the
INVESTIGATING SCIENCE WITH CHILDREN
Series

These six handbooks for the teaching of science in the elementary school have the distinguished sponsorship of two leading groups concerned with the improvement of science teaching: NSTA (The National Science Teachers Association) and NASA (The National Aeronautics and Space Administration). Initiated by NSTA, the series received technical and financial assistance from NASA. The six authors were carefully chosen by NSTA and NASA from among leading science educators in the United States and Canada. The series has been carefully planned, developed, and edited over a period of two years. It updates and replaces the widely successful SCIENCE TEACHING TODAY series by Dr. Guy Bruce, published by NSTA in 1950.

General approach and philosophy. As they planned this series of books, members of the writing team were concerned with the following questions: What are some things we can or should do to help teachers as they investigate the world of science with children? In what direction should we move? How can we incorporate into our writings the processes and content of science, the fostering of creativity in children, provisions for children's varying abilities?

The age and culture in which we live demand that children in the elementary schools have a variety of real science experiences that lead them to an understanding of the world about them. Through a variety of science experiences, each individual will come to understand and to use scientific processes and skills, as well as to acquire the specific science learnings that will help him live intelligently.

Since each book in the series is concerned with one area of science and moves from simple concepts to more complex ones within each chapter, *each* teacher, at any grade level, will find that *all* the books have materials that she can use in her teaching.

Question–discovery approach used. Throughout each book, questions are used in several different ways. At the beginning of each chapter is a list of questions that children of different ages might ask. Answers to these questions and others are found when the children become involved in doing the Activities of the specific chapter. Other questions, with answers containing the science information given in parentheses for the teacher, are included within each Activity to help teachers as they guide the children's learning. More questions are listed later, as open-end Activities to be used with those children who may wish to make further investigations.

Organization keyed to varying abilities. To provide for varying abilities of the children in a group and at different grade levels, as well as to make possible a developmental approach to concept formation, the Activities and learnings are purposely not "graded," but are designated by the following symbols: *x* for those Activities involving beginning learnings; *y* for those Activities requiring more skill and involving several learnings; and *z* for those Activities of considerable difficulty and involving more complex thought patterns. An introduction is included with each Activity, which is merely suggestive and which may give the teacher ideas helpful in challenging children's thinking.

Illustrations and format. All six of the volumes are filled with helpful illustrations that will help the teacher as she directs the children's participation in the Activities. A two-column format allows for easy reading and clear organization, for in-class presentation.

Summaries and references. Each chapter concludes with a summary of the main ideas developed by the author. Throughout each book, cross references are made to Activities and science content found in the other books of the series. At the end of each book there is a list of bibliographical references that contain additional science information.

Scientific accuracy assured. One of the concerns of the writing team was the scientific accuracy of the information appearing in each book. To insure such accuracy, leading scientists who are specialists in their respective fields were asked to read and review the content during the preparation of the manuscripts. Their names appear at the end of this section.

It is hoped that this series of books, INVESTIGATING SCIENCE WITH CHILDREN, will be helpful in providing opportunities for children to use many processes of inquiry —investigating, observing, problem-solving, hypothesizing, experimenting, thinking, checking, analyzing—as they try to find the *what, how,* and *why* of the world around them. There are no final answers in these books. Let the series be thought of as a challenge to teachers to further learning.

Acknowledgments. Many people have made this series possible. The authors and series editor wish to express their appreciation to Robert Carleton, Executive Secretary of the National Science Teachers Association, for his confidence in the project and for his many words of encouragement; to Frank Salamon, Specialist in Elementary Science, National Science Teachers Association, for his guidance through various stages of the project; to Everett Collin, Mattison L. Story, and George Gardner, Specialists, National Aeronautics and Space Administration Education Program, for their interest in the project and for their reading of the manuscripts; and to Lila J. Phillips, Editor for this series, Teachers Publishing Corporation, for her suggestions and aid in the preparation of the final manuscripts for publication.

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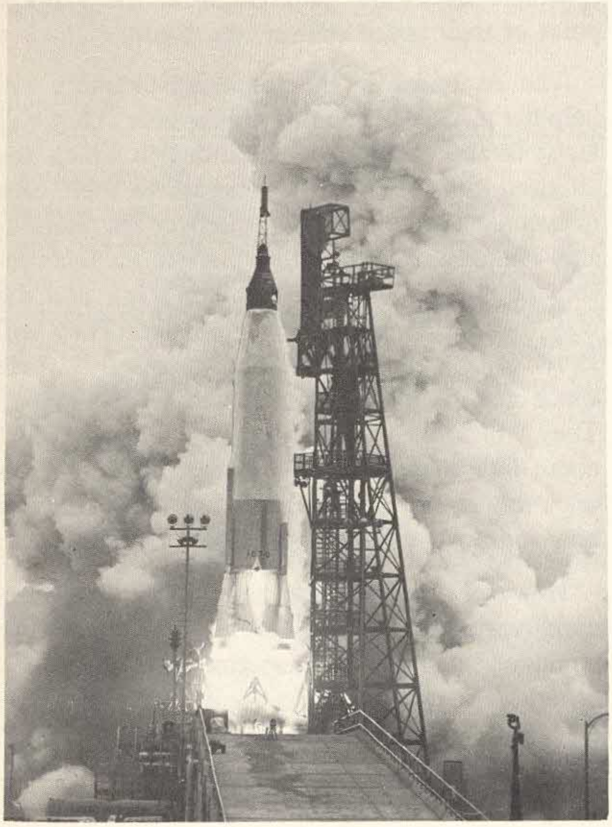
1

INTRODUCTION



"Ten, nine, eight. . . ." The children re-enacted the countdown as their dramatic play began.

"Seven, six, five. . . ." Mike, Sam, and Billy were inside the space capsule, making last-minute preparations for the lift-off.

"All systems go," reported Mike, the flight engineer, as he looked at the dial on the instrument panel they had constructed.

"Guidance system working," reported Sam, the navigator.

"Roger," replied Donald from the blockhouse in the corner of the classroom.

This was the day the fifth graders had been preparing for. They had constructed the rocket out of two discarded cardboard barrels. The capsule, placed on top, was made from packing crates. Cape Kennedy, the launching pad, and the blockhouse were constructed in the corner of the classroom and marked off by bookcases. A discarded television set served as the control board.

Teams had been chosen for the important tasks of constructing the rocket, training the astronauts, plotting the rocket's trajectory, launching the rocket, tracking the spacecraft, and reporting the progress of the Moon voyage. A lot of research had been done to find out how rockets work, how they are launched, and how they are guided.

"Four, three, two . . . ," continued Pam, the launch operations officer.

"Ready for blast-off!" Tim held the wooden microphone close to his mouth as he talked to the tracking stations round the world. Each station was identified by a flag on the large, brightly colored map on the bulletin board.

". . . one, blast off! shouted Pam.

Mary pressed the "play" button on the tape recorder, and the sound of the rocket's engines filled the room with a thunderous roar.

"Oh! This is fun," exclaimed Sarah. "I wish we really could go to the Moon!"

"I'd like to go to another solar system," said Lisa, "and see if there could be another planet like the Earth revolving around another star."

"That's impossible," said Larry. "It's too far away for us to send a rocket to another star. Besides, how would you ever get home?"

How would you ever get home? A child's question, perhaps, but when contemplating space, we must be able to think beyond our Earth-bound home. The ways in which we are oriented to the Earth will not necessarily suffice in space. We need to expand and redefine our language so that it has new meaning for use in space; to develop new concepts of time, distance, size, direction, and motion; to look more closely at man's environmental needs and physical and emotional capacities; to determine his abilities to cope with the conditions in space. We need to re-examine our location in the universe and ultimately find that "up," "down," "center," "forward," and "straight" are strictly arbitrary words to which we have attached meaning valid only on the Earth. They will have little meaning in the context of space. We may find that "life," "movement," and "time," as we think of them, are only relative and may take on new connotations as new information is gathered.

Helping children conceptualize the complexity of space while still "attached" to the Earth is a challenge in itself. Feeling "weightlessness" while having weight, imagining "emptiness" while surrounded by objects, measuring "light-years" while having traveled a few thousand miles at most, these concepts afford the child only partial understanding of so vast a subject. However, the openness of the mind of the young child, his uninhibited imagination, and his natural curiosity allow him to wonder about the nature and extent of the cosmos, to hypothesize about conditions in space, and to communicate with the unknown universe.

Questions that children raise can help to guide the teacher in the study of space. How far is it to the stars? Where does space begin? What is space? How do we know the Earth is turning? What makes night and day? Can I go to another planet some day?

The teacher needs to encourage many experiences in school that will help the child go beyond the limitations of the immediate environment. He must provide opportunities for pupils to experience the evident principles and phenomena that govern the universe and must himself become an ardent participant in the excitement of the space age. He must create an atmosphere in which children enthusiastically explore, experiment, and speculate about the universe from the vantage point of their space station: the Earth.

The Activities in the following chapters will help the teacher create this atmosphere. They will assist in the creation of situations in which the children can discover the answers to their own questions. The children will discover the relationship of the Earth to the other planets, the relationship of the solar system to other stars, and the way the Earth travels through space. They will learn of the instruments man uses to explore space and of the ways in which he uses them. They will learn about rockets and satellites and about how man plans to use these to further his exploration of space. And they will discover how man can exist in space once he gets there.

However, the primary responsibility will remain with the teacher, for it is only with his guidance that the proper atmosphere for discovery can be attained.

2

INVESTIGATING WHERE WE ARE IN SPACE

The space age might be said to have begun on October 4, 1957, when the Soviet Union placed the first man-made Earth satellite, Sputnik I, into orbit. Therefore, many elementary school children have been born during the space age, and certainly all of them have lived the greatest part of their lives in it. Thus it is to be expected that many of the questions they ask will be about the Earth and space:

"How high up does the air go?"

"What is a light-year?"

"What is an orbit?"

"How does man measure the distances between planets?"

"Is the Earth the biggest planet? The smallest?"

Of course, man knew the answer to many of these questions long before the space age began. Nevertheless, they are important questions. An understanding of the Earth's position in space is of the utmost importance, for unless the children achieve this, they will be unable to understand how man explores space.

The main concepts developed in this chapter include:

- We on Earth occupy, and are traveling through, space.
- Man has devised mathematical means with which to measure space.
- Objects in space are in motion.
- Space is vast.

HOW IS DIRECTION FOUND IN SPACE?

We usually think of space as the part of the universe lying outside the limits of the Earth's atmosphere. However, space is that dimension in which all heavenly bodies, including the Earth, move.

ACTIVITY 1 (x)

DISCOVERING THAT OBJECTS OCCUPY SPACE

Purpose: To develop the concept of space

Concept to be developed: All objects occupy space.

Materials needed:

Water
Tubs
Tanks or basins
Wide-mouth jar
Marbles
Sand
Alcohol or sugar
Chart paper or butcher paper
String
Crayons

INTRODUCTION: Too often we think of space only as it relates to that which is beyond our Earth. Listening to children's conceptions and misconceptions of space may lead the teacher to see the need to alter or reinforce learnings. Some children think space begins above the clouds. Some think it is the sky. Some will know the approximate distances at which scientists have measured space. Perhaps some children will also know that, in order to qualify as an astronaut, a man must have flown to an altitude of 50 miles. International law sets 62 miles above the Earth as the beginning of space. Bring up such questions as: Is this really where space begins? Does space have a beginning or an end? What is space?

Have a child fill a jar with water and put his fist in the jar. Let him discover that the water overflows because his hand takes up space. Point out that water was pushed out of the space where his hand is now. Invert an "empty" jar in a tank of water. Does the water rise inside the jar? *(No.)* What occupies the space in the "empty" jar? *(Air occupies the space.)*

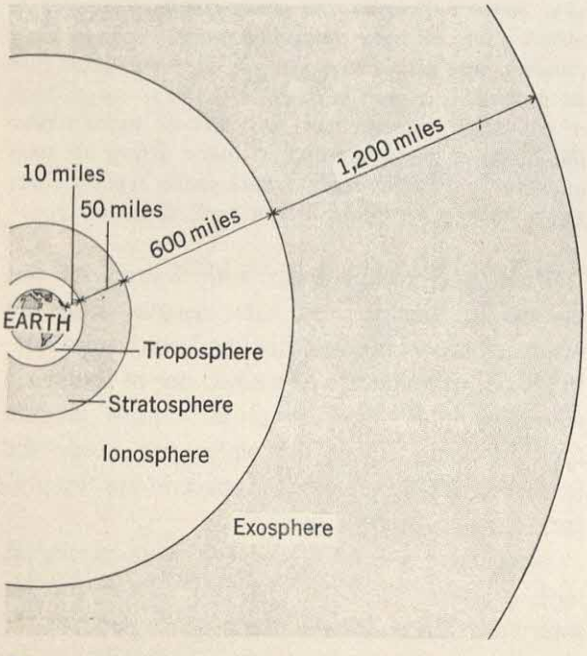
Next, have a child fill a large, wide-mouth jar with marbles. Ask the children, "Does the jar look full? Can you see some space left in it?"

Have the child add some clean sand and shake the jar, then add more sand. Then ask the children, "Is it full now, or is there any space left?" Have a child add water to the jar. Ask the children if they notice anything coming out of the jar. (They should.) Ask them what they think it is. *(Air bubbles.)* Try adding some alcohol or sugar to the full jar. Bring out that each time they add something, they are filling up space. (Actually, empty space is that dimension or condition in which there is an absence of anything.) Between the sand and grains there was space. Even between the water molecules there was space.

There is space all around us. You may wish to distinguish between the space within objects and the space outside the Earth's surface. The latter may be called *outer space.*

Help the children generalize that we take up space. Our bodies take up space. The school takes up space. The Earth occupies space. All objects occupy space. Can the children think of things that might not occupy space? Have them look in a dictionary or encyclopedia to find out what space is.

Extending Ideas: Some of the children might like to construct a chart similar to the one shown in the illustration. Using chart paper or wrapping paper, string, and crayons, they can show the various layers of density from the center of the Earth to the edge of space and beyond. Help the children gain some understanding of the idea that more space is available as one travels farther from the center of the Earth.



To the chart, the children can add the answers to such questions as: How far does our atmosphere extend? How high has man traveled? What is meant by cislunar, intergalactic, and interplanetary space?

Learnings: All objects occupy space. Space is all around us.

ACTIVITY 2 (x)

DISCOVERING RELATIVITY IN TEMPERATURES

Purpose: To introduce the idea of relativity, that is, that we can describe certain objects and events in relation to other objects and events

Concept to be developed: Certain words have meaning only in relation to other words.

Materials needed:

3 bowls
Heated water
Tap water
Ice water

INTRODUCTION: Mention to the children that we become acquainted early with words such as up *and* down, east *and* west, *and* north *and* south. *Explain that each of these terms has meaning because it is used in relation to where we are on the Earth. When we say, "up," we usually mean away from the Earth's center. When we say, "down," we usually mean toward the center of the Earth. When we say east or west or north or south, we are referring to the cardinal points of the compass. But in space these terms have little or no meaning. It all depends where we are. To help the children understand this concept of relativity, ask three children of different heights to come to the front of the room. Begin by stating that "John is a tall boy." Then ask the children to compare his height to each of the two others: Who, in each pair, is taller? Who of the three is tallest? Ask a fourth child to join the three. Now, in each pair, who is taller? Who of the four is tallest?*

Place bowls containing heated water, tap water, and ice water on your desk. Have a child put his hand in the tap water. Ask the child, "Is it warm or cold?" If he says, "warm," have him put his other hand in the heated water. Does he still think the tap water is warm? If he says, "cold," have him compare the temperature with that of the ice water. Help the children see that the temperature terms we use are relative. Such words as *warm, cold, tall, heavy, far,* and *near* are all relative depending upon your point of reference.

Ask the children if they can think of other words that have meaning only when they are related to a given location, time, or degree.

Learning: Some words have meanings only in relation to other words.

ACTIVITY 3 (x,y)

DISCOVERING RELATIVITY IN LOCATION

Purpose: To illustrate that the appearance of objects depends upon the location from which they are viewed

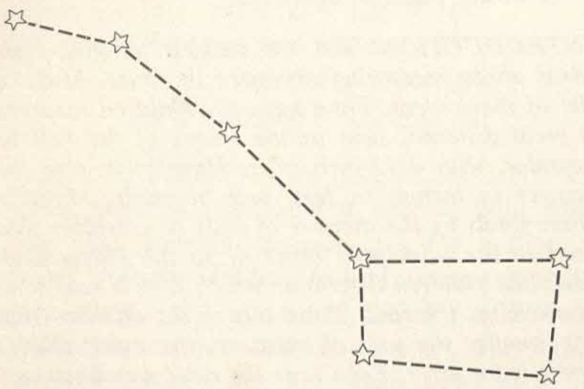
Concept to be developed: The appearance of objects is relative.

Materials needed:

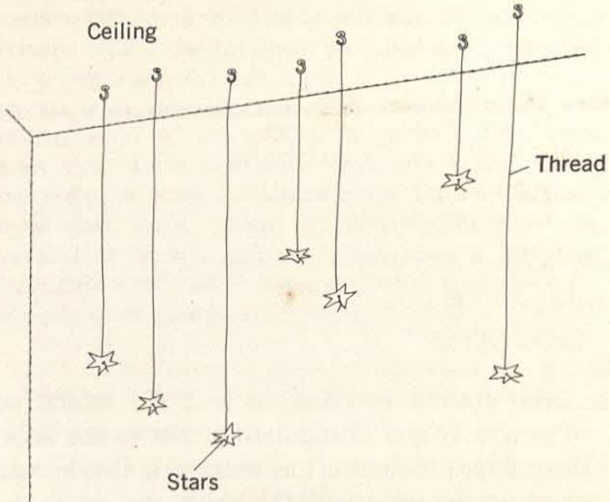
- Thread or string
- Paper
- Ladder
- Pins or tacks

INTRODUCTION: Have the class read, or read to them, the age-old fable, The Blind Men and the Elephant. *Discuss with them the meaning of* relativity. *Help them see that many observations are relative to the observer's position in time and space.*

To form the shape of the Big Dipper constellation, suspend round pieces of paper representing stars by strings or thread from the classroom ceiling. The strings should be of different lengths.



Try to make the constellation cover about a four-foot radius. Have children look up to the ceiling from their chairs or desks. They will see the familiar constellation, the Big Dipper, which will look something like the one shown in the illustration. Have each child draw exactly what he sees. The children will find that each picture differs slightly, depending upon where the artist was sitting in the room. To some the dipper will appear to "hold water," to others it will look as if it is pouring water out, and to others it will appear to be standing on one end. Now have several children go out "into space" by standing on a ladder, a chair, or a desk. Have them view the constellation from various points in the room. Again, ask them to draw what they see. Their drawings may look something like the illustration. Have them compare their second drawings with what they originally saw from "the Earth" (the floor). Ask the children which is the top of the dipper. Which is the bottom? *(There is none. It all depends on where you are on the Earth or in space.)*



Learning: The appearance of stars and constellations viewed from space will be different from the way we are used to seeing them from the Earth.

ACTIVITY 4 (x,y)

DISCOVERING RELATIVITY IN MOTION*

Purpose: To show that motion, too, appears different from various positions

Concept to be developed: Motion is a relative phenomenon.

Materials needed:

- Chalkboard eraser
- Ball
- Chair

---

*For a further discussion of relativity in motion, see *Motion*, by Lois Dunn (Investigating Science with Children Series; Darien, Conn., Teachers Publishing Corporation, 1964).

INTRODUCTION: Discuss with the children the feeling they may have had when they traveled in a train or car. Have they noticed that objects close up seem to whiz past very rapidly while objects farther away seem to move slowly? Have they ever had the experience of facing one way in a car or train while looking at another car or train headed in the other direction? Did they think they were moving forward when actually it was the other car or train that began to move? Have they ever watched a high-flying airplane while they were traveling in a fast-moving car in the same direction? Did the airplane seem to hang almost motionless in the sky? Why?

Ask a child to stand on a table, ladder, or chair and drop a chalkboard eraser to the floor. Have three children act as observers. One should stand on the table with the child who drops the eraser. Another should stand or squat on the floor. The third should lie on his back on the floor close to where the eraser falls. Each of the observers should describe the path of the eraser as seen from his vantage point.

Ask three other observers to trace the path of a ball as it is rolled across the room or playground in a "straight" line. Spin the ball in an attempt to make it curve as it rolls along its path. Compare what each observer sees.

Learning: The motion of an object can be described only in terms that are relative to the point from which the motion is observed.

Summing Up Ideas: In this section, the children were introduced to the idea that we are in space. They should also have learned that "outer space," is the space around the Earth. In addition, they were introduced to the concept of relativity and the fact that many words only have meaning relative to other words or to points from which objects or motions are viewed.

HOW IS SPACE MEASURED?

How many inches is it from New York City to Calcutta, India? We wouldn't think of measuring such a distance in inches, although it is possible to express it that way. How shall we measure distance in space? Our Earth-bound system of measurement does not suffice because space distances are so great. We need some new units of measurement, so that numbers do not become unwieldy. When measuring space distances, if only miles were used, it would be like measuring how far it is from New York City to Calcutta, India, in inches. To measure distances in space, scientists have set larger units of measurement. One of these is called a light-year.

A *light-year* is the distance light travels in one year. (Note that it is not a measure of time but rather one of distance.) Scientists have determined how fast light travels in a given period of time. It travels about 186,000 miles in one second. The following Activities will establish how far light will travel in one year and how we use this information to give us a unit large enough to measure distances in space.

There are several ways to measure distances in space. This section suggests Activities for developing an understanding of some of these procedures.

ACTIVITY 5 (y,z)

MEASURING THE DISTANCE LIGHT TRAVELS IN ONE YEAR

Purpose: To introduce one of the units of measurement of space distances, the light-year

Concept to be developed: A light-year is the distance light can travel in one year.

Materials needed:

12-inch ruler
Pencil and paper for each child

INTRODUCTION: Ask the children to give their ideas about measuring distances in space. Make a list of these ideas. Then have the children measure a great distance, such as the length of the hall or corridor, with a 12-inch ruler. Have them give the answer in inches, in feet, and in yards. Multiply these totals by the number of halls or corridors that lead to the principal's office or to the playground. Help the children determine which unit is easiest to work with. (Yards.) *Point out to the children that the smaller the unit of measure, the more chance there is for error. Each time the ruler was lifted and set in place again, another chance for error was introduced. The children may wish to repeat their measurements several times to check for accuracy. Ask the children, "Why not use another unit instead of yards? Could you invent a new unit of measure larger than yards but smaller than miles?"*

Then introduce the concept of the light-year *to the children. Before defining it for them, you may want to have them speculate about what it might mean. Point out to them that we often use units of measure that combine seemingly unrelated words, such as* foot-candle, kilowatt-hour, foot-pound, *and* man-hour. *Have the children look these words up* *in a dictionary and explain what they mean. Then tell them that they can compute how great a distance a light-year is.*

Children enjoy "playing" with large numbers. It's fun to speak in terms of billions and trillions. Even though such large numbers may have little meaning, using them may give the children a feeling for the immensity of space. If they know light travels about 186,000 miles in one second, children can figure out how far it travels in one year. To make this calculation, they will need to multiply 186,000 by the number of seconds in one minute (60), the number of minutes in one hour (60), the number of hours in a day (24), and the number of days in a year (365¼):

$$186{,}000 \times 60 \times 60 \times 24 \times 365\tfrac{1}{4} = 5{,}869{,}713{,}600{,}000,$$

or nearly 6 trillion (6,000,000,000,000) miles.

Point out that sometimes, to save time and energy, large numbers can be simplified by dividing by multiples of ten. The large number 6,000,000,000,000 can be written 6×10^{12}. Explain that this is just another way of saying 6 with 12 zeros after it. Have the children practice writing large numbers in this simplified fashion of dividing by multiples of ten. (Tell them to be careful about the position of the decimal point.)

$$\begin{aligned} 186{,}000 &= 186 \times 10^{3} \\ 24{,}000{,}000 &= 24 \times 10^{6} \\ 5{,}290 &= 5.29 \times 10^{3} \\ 2{,}222{,}000{,}000 &= 2.222 \times 10^{9} \end{aligned}$$

Extending Ideas: As we gaze at the stars on a clear night, we are able to receive light which has been traveling to our eyes for millions of years. Ask the children to look in encyclopedias, star charts, and atlases of the sky to find distances to various well-known stars. Have them determine how many light-years away these are. How many miles away are they? The closest star, next to our Sun, is Proxima Centauri. Its light takes about 4.3 light-years to reach the Earth. How many miles away is it? Polaris, the North Star, is 40 light-years away. The Andromeda galaxy is nearly 2×10^{6} light-years away. How many miles away are they?

Some children may wish to look in the encyclopedia and report on the life of the Nobel Prize winner Albert A. Michelson, who devised a method for measuring the speed of light.

Learnings: The light-year is one of the units we use when measuring distances in space. One light-year equals almost 6 trillion (6,000,000,000,000) miles.

ACTIVITY 6 (x,y)

COMPARING LIGHT AT VARIOUS DISTANCES

Purpose: To show that the brightness of a light source decreases with its distance from an observer

Concept to be developed: Distances to stars can be determined by studying their light. The farther away a light is, the fainter it seems. Therefore, distances can be calculated by the relative brightness of stars.

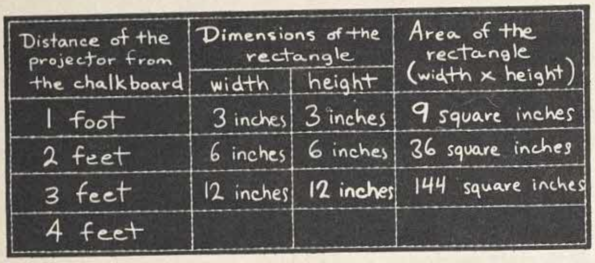
Materials needed:

2 identical flashlights
Slide or filmstrip projector
Yardstick
Chalk
Photographer's light meter

INTRODUCTION: Ask the children to suggest possible ways we might use starlight to determine how far away the stars are. Have them look at stars. What do they notice about them? Are all the stars the same size? Are they all equally bright? Are any of them moving?

Take the class into an auditorium or other room that can be darkened. Use two identical flashlights with new batteries in each, so that the amount of light is the same. Have one child stand in a far corner of the darkened room, holding one flashlight that is shining. Another child, holding the second shining flashlight, should stand close to the rest of the group. Ask the children, "Which seems brighter?" (The closer would seem brighter. If this could be done at night and the two lights were separated by an even greater distance, it would be still more effective.) *Ask the children if they have noticed when they are out at night that street lamps and electric signs seem brighter when they are closer. Likewise, although two stars may be of equal brightness one may seem dimmer if it is a greater distance from Earth.*

Have one child draw on a chalkboard a horizontal line one yard long and mark off thirty-six 1-inch intervals on it. Place the projector exactly 1 foot from the chalkboard and turn it on. Ask another child to focus the light on the horizontal line. How many inches of the line are lighted? Move the projector back 1 foot. Now how many inches does the light cover? Can the class find the area of the square of light? Move the projector back another foot and measure the distance covered by the light again. Has the amount of light hitting the chalkboard changed? *(No. It has just spread out and therefore seems dimmer.)* Have the children make a table of distances and areas of the rectangles of light on the chalkboard, as shown in the illustration. The area of the rectangle of light is found by multiplying the width of the rectangle by its height. This amount will vary for each projector and lens.



Distance of the projector from the chalkboard	Dimensions of the rectangle		Area of the rectangle (width × height)
	width	height	
1 foot	3 inches	3 inches	9 square inches
2 feet	6 inches	6 inches	36 square inches
3 feet	12 inches	12 inches	144 square inches
4 feet			

Next place a slide or filmstrip in the projector. Shine the picture on the wall from a distance of 2 feet. Move the projector back to 6 feet. Now move it as far away as possible. When is the picture the brighest? *(When the projector is closest.)* When is it the dimmest? *(When the projector is farthest from the wall.)* Has there been a change in the amount of light produced? *(No.)* Why does the light become dimmer when the projector is moved back? *(It is spread over a greater area.)*

Secure a light meter. Take readings of the light falling on the chalkboard when the projector is various distances away. Have the children make a table of the readings and the distances at which they were measured.

Extending Ideas: One way to determine distances to the Moon or planets is to send radar signals and "bounce" them off the Moon or the planets. If one knows how fast radar signals travel and the time it takes for the signal to go and come back, the distance can be calculated. For example, if a signal is sent to a planet, bounces off, and is received back on Earth 10 minutes later, the distance of the planet from Earth can then be determined. It took 5 minutes for the light to travel to the planet and 5 minutes for it to return. One-half the total time the signal traveled (in seconds) multiplied by the number of miles the radar signal traveled in one second (186,000 miles), ½ × 10 minutes × 60 seconds/minute × 186,000 miles/second, gives the distance to the planet. Thus, ½ × 600 × 186,000 = 300 × 186,000 = 55,800,000 miles (55.8×10^{6} miles).

Have the children look in books to find the distance from the Earth to the other planets in the solar system. How long would it take for a radar signal, traveling at the speed of light, to travel from the Earth to Mars and bounce back again? Some children may wish to find out more about how radar works. Possibly someone in your community works with radar in the military service, as an electronics engineer, or at the airport. Perhaps he could explain to the class how radar operates.

Learnings: Although the brightness of a light source may not change, it appears brighter or dimmer according to its distance away from an observer. Thus, distances to stars may be measured by comparing their light intensities.

ACTIVITY 7 (y,z)

LEARNING ABOUT TRIANGLES

Purpose: To establish basic facts about triangles to enable the children to learn about triangulation

Concept to be developed: Triangulation is a means of determining distances.

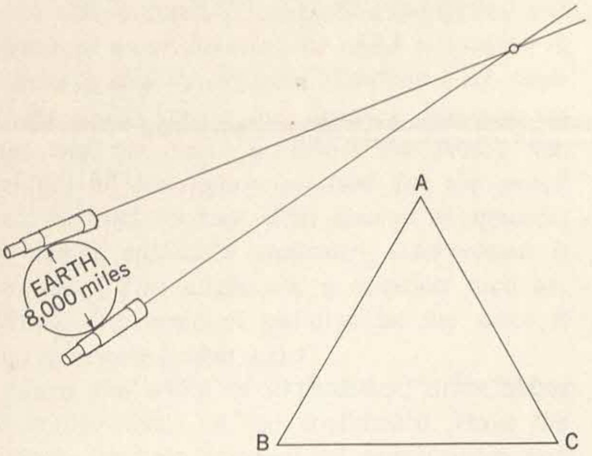
Materials needed:

- 12-inch rulers
- Pencils
- Protractors
- Graph paper

INTRODUCTION: Another way to measure distance in space is by using triangulation. *Triangulation involves measuring three particular parts of a triangle, such as two angles and the side between them. When the sizes of these three particular parts of a triangle are known, the sizes of the other three parts can be determined. This process will be brought out in the following Activities.*

As the Earth rotates, astronomers can take two sightings with telescopes or cameras, one from each side of the Earth, toward the Moon or planet and measure the angle between each line of sight and the diameter of the Earth. In this way, they have constructed a triangle in space, and they know the size of three of its parts.

Using the protractors, have the children practice measuring angles. Have them draw several circles and measure the number of degrees in the angles formed when several *radii* are drawn. The radius is the distance from the center of the circle to its edge. Place the protractor on the

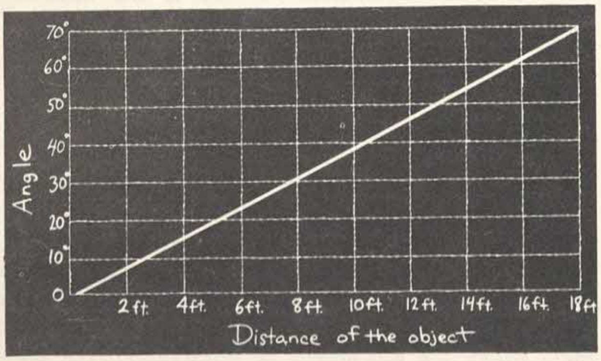


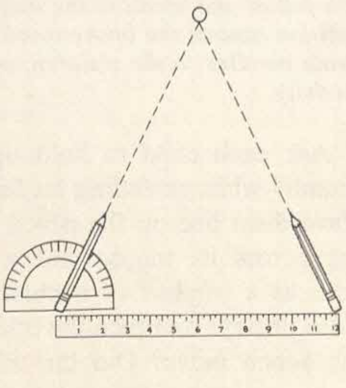
THE PARTS OF A TRIANGLE

Angle BAC	Side AB
Angle ABC	Side BC
Angle ACB	Side AC

angle so that one radius is on 0°. Count the number of degrees in each angle.

Let each child lay a ruler on his desk and place a pencil at each end. Have the children point the pencils at various objects in the room. Help them use the protractor to measure the varying angles between the pencils and the ruler. Help them discover what happens to the size of the angle when the pencils are pointing to a close object; when pointing to a distant object. Have them keep a record of their measurements. They can make a graph comparing the angle made by *one* pencil to the distance of the object.





Learnings: The parts of a triangle are related to one another. The shorter the distance from the apex of the triangle to the base, the smaller will be the angle the sides of the triangle make with the base.

ACTIVITY 8 (y,z,)

USING TRIANGULATION TO MEASURE DISTANCES

Purpose: To measure distances by triangulation

Concept to be developed: Three parts of a triangle can be found by using the Earth's diameter as a base line. Therefore, the distance from the Earth to other bodies in the solar system can be calculated.

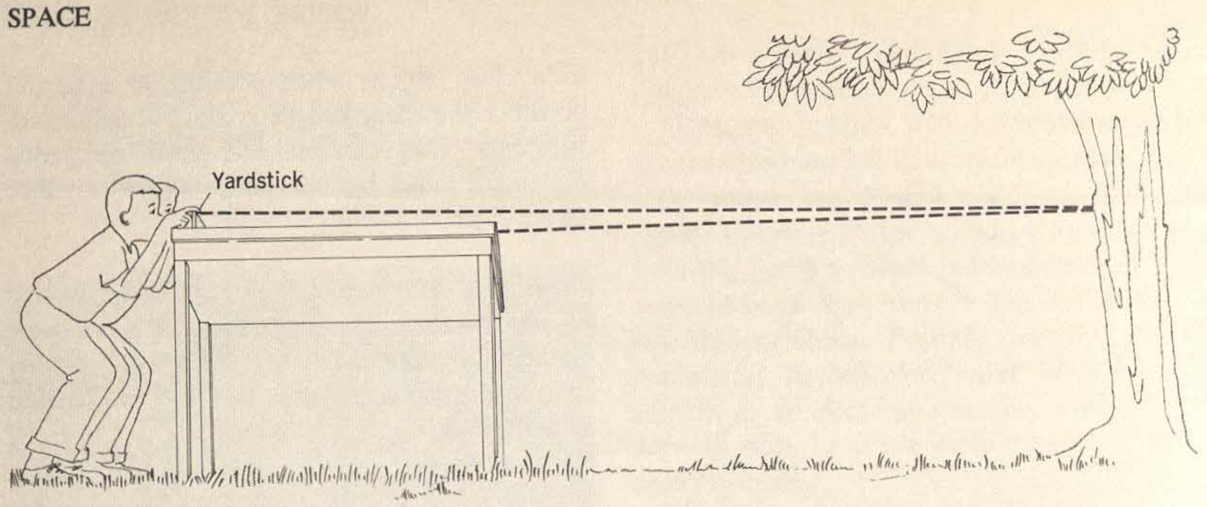
Materials needed:

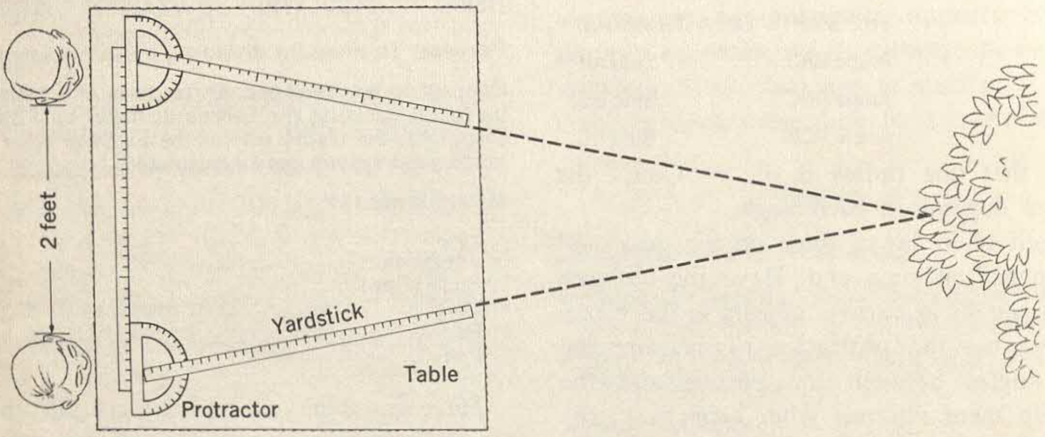
- Table
- Yardstick
- Soda straws
- Pins
- Paper
- Pencils

Have the children insert straight pins through the walls of two soda straws, making sure they insert the pins as close to the middle of the straws as possible and push them all the way through. Then ask the children to pin the straws to the yardstick at the "6-inch" and the "30-inch" marks so that they are exactly 2 feet apart.

Take a table out into the schoolyard and have two children stand two feet apart on one side of the table. Place the yardstick on the table between the two children. Have each child close one eye and sight through a straw on the yardstick toward a tree or pole across the playground. When the children have "focused in" on the tree or pole, measure the angle between the soda straw and the yardstick with a protractor. Now three parts of the triangle are known.

Now suggest that the children reconstruct this problem on paper in the classroom, using a scale of 1 inch to 1 foot. Have them place a ruler on a piece of paper and draw a 2-inch base line. With their protractors, have them make the same angles that were obtained when the tree or pole was sighted through the straws. Using these angles, ask them to draw a line from





each end of the base line and extend the lines until they intersect. Now have them measure the distance from where the lines intersect to the 2-inch base line. Using the same scale of 1 inch equal to 1 foot, have them express their answer in feet. Ask the children, "How far was it to the tree?" Let several children actually measure the distance now to check the accuracy of their reconstruction.

Have the children measure distances to various objects on the school grounds, using this method. Can the children see that calculations of distances to various objects can be made indirectly without actually having to go to that object?

Learning: By means of triangulation, the distance from an observer to an object can be measured.

ACTIVITY 9 (z)

MEASURING PARALLAX

Purpose: To demonstrate another means of measuring the distances of stars from the Earth

Concept to be developed: Parallax is the apparent change of position against a stationary background of an object sighted from two different locations.

Materials needed:

Pencil
Chalk
Yardstick
Protractor

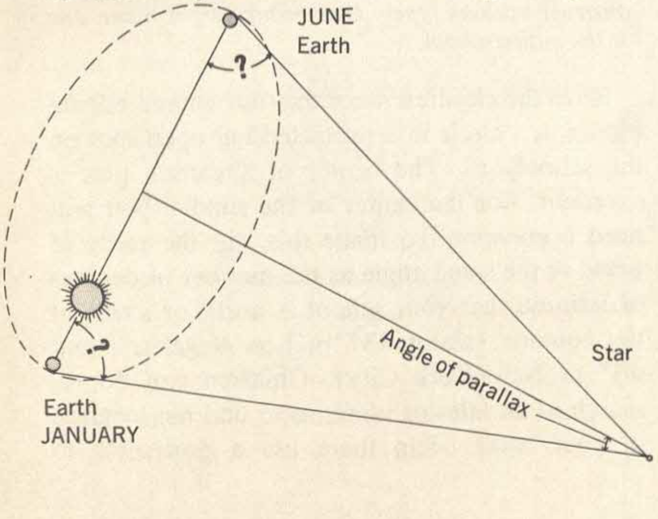
INTRODUCTION: Parallax is the apparent change *of position of an object sighted from two locations against "stationary" background objects. As astronomers watch the movement of celestial objects, they can follow and measure the apparent change in their position against the background of stars. To demonstrate parallax to the children, perform the following Activity.*

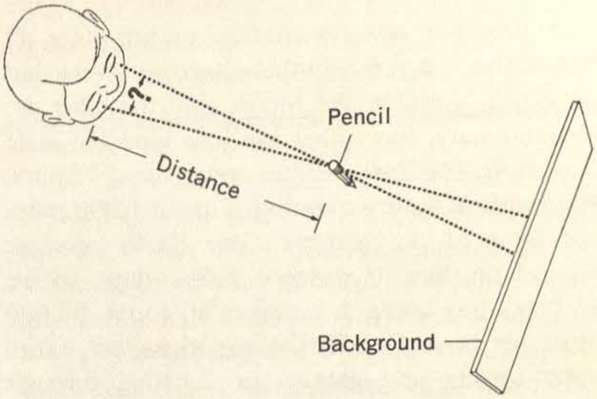
Ask each child to hold up a pencil (or his thumb) while extending his hand at arm's length. Have them line up the pencil or thumb by looking across its top toward a stationary object, such as a window or a chalkboard. Have them close one eye and then the other. Ask them, "Did the pencil move? Did the window move? How much did it appear to move?" *(The pencil will appear to move because the child is looking at it from a slightly different direction each time. If the child knows the distance between his eyes and the angle at which the pencil was sighted, he can figure out how far the pencil must be from his face. This amount of apparent movement against a stationary background is parallax.)* You might ask a question such as: "Would the angle of parallax be the same if your eyes were farther apart?"

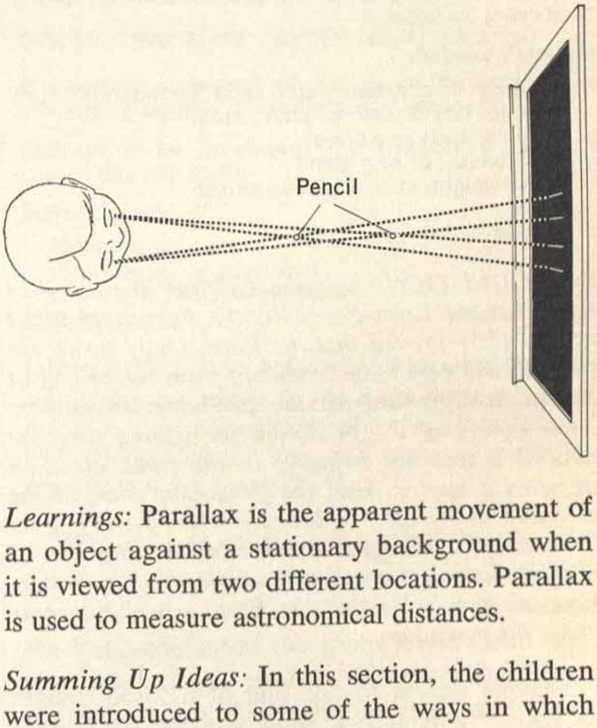
Using the width of a yardstick, draw about 20 vertical lines on the chalkboard. Have the children hold up a pencil or thumb again and repeat the Activity, using the lines on the chalkboard as the background. Ask them to count how many lines the pencil "moves" as they open and close each eye. Have them vary the distance between their eyes and the pencil. Does the number of lines the pencil "moves" increase or decrease as the pencil is moved closer to their eyes? *(It increases.)*

Ask two students seated on opposite sides of the room to view an object, such as a vase or a book, placed on a desk toward the front of the room. Ask each to describe what he sees behind the object. Does each child see the same background? *(No.)*

Extending Ideas: Much of the information about space is obtained with instruments right here on Earth. By using knowledge of mathematics and the characteristics of light, astronomers have determined much information about distances in space. Perhaps there is an observatory or planetarium in your area that you can visit. Perhaps an astronomy student from a nearby college or university can come to talk to your class. Some children may wish to read about Tycho Brahe, Johannes Kepler, and Albert Einstein to see what these famous men have contributed to our knowledge of the nature of light, time, and space.







Learnings: Parallax is the apparent movement of an object against a stationary background when it is viewed from two different locations. Parallax is used to measure astronomical distances.

Summing Up Ideas: In this section, the children were introduced to some of the ways in which space is measured. They learned of one of the units of measurement, the light-year, and that 1 light-year is equal to about 6 trillion (6,000,000,000,000) miles. They also learned about triangulation and how it is used to measure distances in space, using the diameter of the Earth as a base line. They were also introduced to the concept of parallax and shown that parallax is the apparent movement of an object against a stationary background when it is viewed from two separated locations.

WHERE ARE WE GOING IN SPACE?

If children can observe changes taking place all around them, it can help them become aware that the Earth, the Sun, the Moon, and the stars are not stationary, but rather are in a constant state of motion. The Earth *rotates* once every 24 hours, which means we are spinning at about 1,000 miles per hour at the equator. The Earth *revolves* around the Sun once every 365¼ days, so we are traveling around the Sun at about 66,600 miles per hour. Besides these motions, our entire solar system and galaxy are hurtling through space.

ACTIVITY 10 (y,z)

DEMONSTRATING A FOUCAULT PENDULUM

Purpose: To show that the Earth rotates on its axis

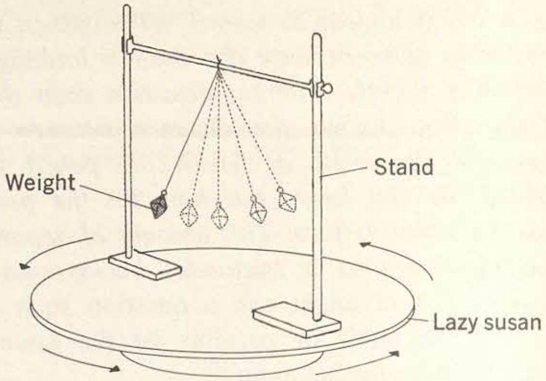
Concept to be developed: The Earth rotates on its axis once every 24 hours.

Materials needed:

- Rotating mechanism such as a phonograph turntable, lazy Susan, or piano stool
- Support, such as a dowel
- Wastebasket or ring stand
- Heavy weight, such as a lead sinker
- String
- Clamps

INTRODUCTION: Tell the children the story of Jean Bernard Leon Foucault, the French physicist who in 1851 proved that the Earth really turns. He suspended a very long pendulum from the ceiling of a high building and set the pendulum in motion. After observing the pendulum for a long time, he noticed it was not swinging in the same direction as when it started. Had the pendulum changed the direction of swing? No, because when a body is set in motion, it continues to move in that direction of motion unless something changes its direction. Foucault concluded that the Earth must be turning under the pendulum.

Tie the weight to one end of a 2-foot length of string. Attach the other end to a 1½-foot piece of dowel or broom handle. Place the dowel across the top of a wastebasket, ring stand, or other such support, allowing the weight to swing freely. Place the support on top of the lazy Susan or piano stool. Set the weight swinging and then rotate the lazy Susan or piano stool very slowly.



As the setup turns, ask the children what happens to the direction of the swing of the pendulum. Does it change direction, or does it continue to swing in the same direction? *(It should continue to swing in the same direction.)* How did Foucault apply this to the rotation of the Earth?

Learning: The Earth rotates on its axis.

ACTIVITY 11 (x,y,z)

MAKING A SUNDIAL

Purpose: To show how the movement of the Earth is used to "tell time"

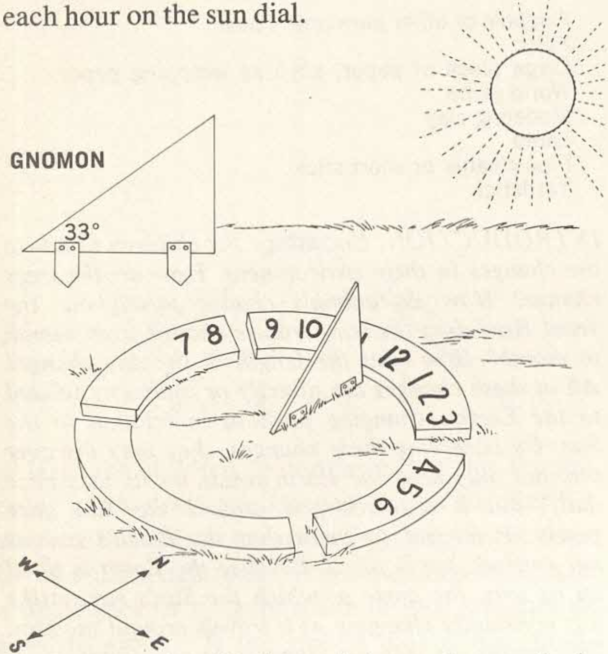
Concept to be developed: The Earth's rotation makes the Sun appear to move across the sky.

Materials needed:

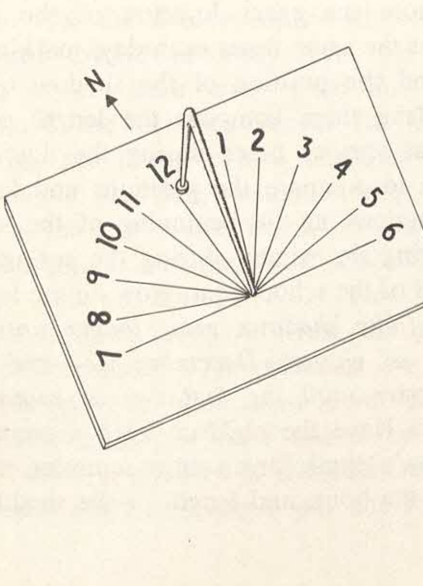
- Knitting needle or strong wire
- Cardboard or soft wood, 1 foot square
- 4 quarter-circle edging blocks from a nursery or building supply store (the kind used to line flower beds and separate them from lawns)
- Piece of redwood or cedar about 1 foot wide and as long as the radius of the circle of edging blocks
- Nails
- Small pieces of scrap redwood or cedar

INTRODUCTION: Another way to help children gain the concept of the Earth's rotation is through constructing a sundial. Sundials can be simple or complex, according to the time and energy spent. Perhaps several groups of children will wish to construct various types. One group might make one for the entire school.

Have the children place the four curved edging blocks in a circle in a protected but open spot on the schoolyard. The center of a garden plot is excellent. For the center of the sundial you will need a *gnomon.* To make this, cut the piece of wood at the same angle as the number of degrees of latitude that your school is north or south of the equator (about 33° in Los Angeles, about 40° in New York City). Children can do research in an atlas or almanac to find the location of your town. Help them use a protractor to draw this angle. Nail some stakes to the wood so it will stand firmly in the center of the sundial. Place the gnomon in position so that the point of the angle of the wood at the center of the circle points directly south. When the shadow cast on the circle is at its thinnest, the time is exactly noon, sun time. Each time the shadow widens by 15 degrees, an additional hour has passed. Mark each hour on the sun dial.



A more simplified sundial can be made by inserting a knitting needle or similar strong wire into a heavy, 1-foot-square piece of cardboard or soft wood. If desired, the knitting needle may be bent to the angle corresponding to your latitude. Take the sundial out of doors or to a window sill. Follow the procedure of marking the cardboard where the needle casts its shadow, precisely at each hour of the day.



Extending Ideas: Have children list some reasons why the sundial is not a suitable timekeeper. Some children may wish to read further about other time-keeping devices. Early civilizations had methods for keeping track of time. Can the children find what they were?

Discuss with the children how a sundial would differ if it were south of the equator or on the equator. What effect does bending the gnomon to the angle of your location on the Earth have on the sundial? Could you make a sundial out of your school's flagpole? Some children may wish to do research in an encyclopedia or other book to explain other types of time: sidereal time, Earth time, and real time.

Learning: The rotation of the Earth makes the Sun appear to move.

ACTIVITY 12 (x,y)

DISCOVERING WHAT CAUSES NIGHT AND DAY

Purpose: To show that the rotation of the Earth causes alternating periods of daylight and darkness

Concept to be developed: The rotation of the Earth causes day and night.

Materials needed:

Modeling clay
Pipe cleaner or short stick
Flashlight, lamp, or projector
World globe

INTRODUCTION: Ask the children what they think causes day and night. As the Earth turns on its axis, half of it is lighted while the other half is in darkness. This motion causes day and night, and the Sun appears to move across the sky.

With a lump of modeling clay, secure a stick figure or flag to a world globe. (If a globe is unavailable, a white volleyball will do.) Place the lump of clay at the spot on the globe where you are located. Darken the classroom. Use a projector lamp, flashlight, or unshaded electric lamp to simulate the Sun. Rotate the globe slowly. As the light falls on the globe, help the children see that not all the globe is illuminated at the same time. Have them observe what happens when the stick figure comes into "daylight." Ask the children, "Does the figure cast a shadow?" *(Yes.)* "How does the shadow change as the Earth turns?" *(It seems to move.)* "What time would this be where you are?" "What time would it be when the figure is cast into darkness?"

"What causes day and night?" *(The rotation of the Earth.)* "Which way should the globe be turned to make the sun 'rise' in the east and 'set' in the west?" *(From west to east.)* "Does the sun really rise, or does it only appear to rise while the earth is turning?"

Extending Ideas: Suggest that the children play shadow tag during play period or after school to find out more about shadows. Have them also play it in the morning and at noon. When are the shadows the longest?

Learning: Day and night are caused by the rotation of the Earth.

ACTIVITY 13 (y,z)

LOCATING THE EARTH'S AXIS

Purpose: To illustrate the position of the Earth's axis

Concept to be developed: The Earth's axis is an imaginary line around which the Earth rotates.

Materials needed:

Phonograph turntable
World globe

Ask the children to define the word *axis*. Some may wish to look it up in a dictionary or encyclopedia. Then have them examine a phonograph turntable and locate the center point around which the records turn. Point out that this spindle is the axis of the phonograph turntable. Find a world globe that is mounted on a support that allows the globe to spin freely. Ask a child to spin the globe. Have the children locate the Earth's axis. In which direction should the globe spin? *(The sun appears to rise in the east and set in the west; therefore, the globe should turn from west to east.)* Locate the axis of the Earth at the north and at the south. Align the north axis of the globe to true north and spin the globe. This should be the correct position to represent the spin of the Earth. When the children look down on the North Pole of the globe, it should spin in a counterclockwise direction. Have the children locate the equator. What is its position relative to the axis? *(Perpendicular to it.)*

Learnings: The Earth's axis is an imaginary line running through the center of the sphere. The Earth rotates around its axis. The equator is perpendicular to the axis.

ACTIVITY 14 (x,y)

OBSERVING CHANGING SHADOWS

Purpose: To observe the effect of the Earth's tilted axis

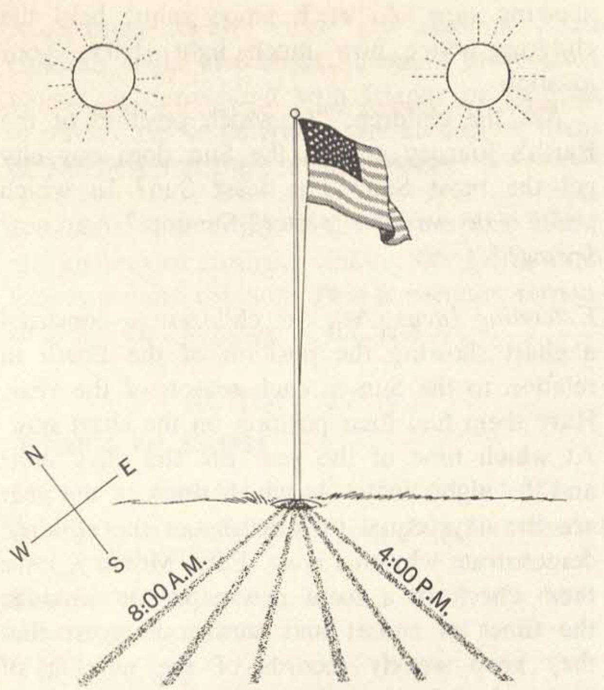
Concept to be developed: The tilting of the Earth's axis causes sunlight to strike the Earth at different angles as the Earth revolves around the Sun.

Materials needed:

Flagpole or other permanent pole
Paint
Large piece of paper, such as wrapping paper
World globe
Modeling clay
Lamp
Pipe cleaner or short stick
Yardstick

INTRODUCTION: Encourage the children to notice the changes in their environment. How do the trees change? How do animals change throughout the year? How does the temperature change from month to month? How does the length of the day change? All of these changes are directly or indirectly related to the Earth's changing position in relation to the Sun. By observing these changes, they may discover that not only does the Earth rotate *on its* axis *once daily, but it also* revolves *around the Sun once yearly. Point out to them that the Earth's axis is not vertical, but is tilted. Because the Earth is tilted on its axis, the angle at which the Sun's rays strike it is constantly changing as it travels around the Sun. This causes the seasonal changes we can detect. Have the children speculate as to what would happen if the Earth's axis were not tilted.*

Have the children keep track of the shadow cast by a pole over a long period of time. If it is possible, paint markings of the shadow's position directly on the surface of the playground. If not, recording them on a large piece of chart paper or wrapping paper will do. The children should note the exact location of the pole's shadow at the same times each day, marking the length and the position of the shadow on the paper. Have them compare the length of the shadow at various times during the day. Also ask them to compare the positions and lengths of the shadows at the beginning of the school year, during the winter, during the spring, and at the end of the school year. How do the lengths change? *(The shadows grow longer until the first day of winter—December 22—and then grow shorter until the first day of summer—June 21.)* Have the children keep a record of the shadow's length for an entire semester, noting the date, the hour, and length of the shadow.



Help the children to conclude that this lengthening of shadows can happen only if the Earth's axis is tilted. Place an unshaded lamp in the center of a darkened room. Have the children attach a small stick or a figure made of pipe cleaners to a world globe. (If the globe's axis is not tilted, it will be necessary to tilt it for the first part of this Activity.) Ask the children to place the globe so that its axis is tilted toward the "Sun" and to measure the shadow cast by the stick. Then have them move the globe to the other side of the unshaded bulb, placing it exactly the same distance from the lamp as it was before. Suggest that they tilt the axis of the globe away from the "Sun" and measure the length of the shadow. Was the shadow longer when the axis was tilted toward or away from the "Sun"? *(When it was tilted away from the "Sun.")* Now have the children repeat the Activity, measuring the length of the shadows cast on both sides of the "Sun," without tilting the axis—that is, the axis of the "Earth" should now be parallel to the axis of the "Sun." Do the lengths of the shadows differ? *(No.)* How do the shadows' lengths compare when the globe is tilted and untilted? *(The shadows are longest when the globe is tilted away from the "Sun" and shortest when it is tilted toward the "Sun.")*

Now ask the children if they can draw any conclusions from this about why the length of the shadow of the flagpole changed throughout the year. *(The Earth's axis must be tilted, just as the globe's was, in order for the shadow to change its length. If the axis were not tilted, the shadow cast by the flagpole would always be the same length.)*

Learning: The axis of the Earth is tilted.

ACTIVITY 15 (z)

LOCATING THE PLANE OF THE ECLIPTIC

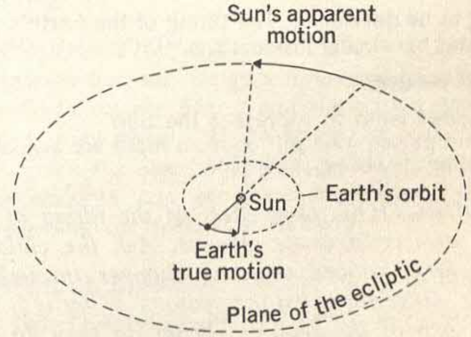
Purpose: To show that as the Earth revolves about the Sun, the Sun appears to follow a path in the sky

Concept to be developed: The apparent path of the Sun is called the ecliptic.

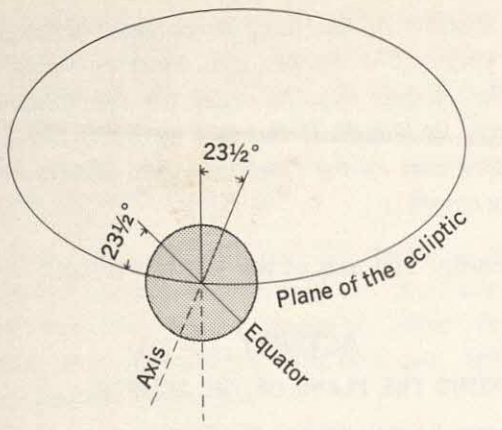
Materials needed:

Protractor
Paper
Pencil
Ruler

The children may do the following to show the plane of the ecliptic. Have them draw a vertical line on a sheet of paper and then, using a protractor, draw an angle of 23½ degrees. Next, ask them to center a large coin, such as a half-dollar, over the angle and draw a circle. Have them extend the lines of the angle, draw a diagram of the Earth and the angle at which the axis is tilted, and draw in the equator. Finally, ask them to measure the angle between the equator and a line drawn parallel to it.



After the children have completed their drawing, ask such questions as: "What is the angle at which the equator is tilted?" *(23½°.)* "If th line of the axis were extended into space, wh star would it intercept?" *(The North Star.)* the horizontal line were continued into sp



around the Sun, it would trace the path of the Sun around the Earth. This is called the ecliptic and the plane in which it lies is called the plane of the ecliptic.

Learning: The apparent path of the Sun about the Earth is called the ecliptic.

ACTIVITY 16 (x,y)

DISCOVERING SEASONS

Purpose: To show why seasonal changes occur on the Earth

Concept to be developed: The tilting of the Earth's axis contributes to causing the seasons.

Materials needed:

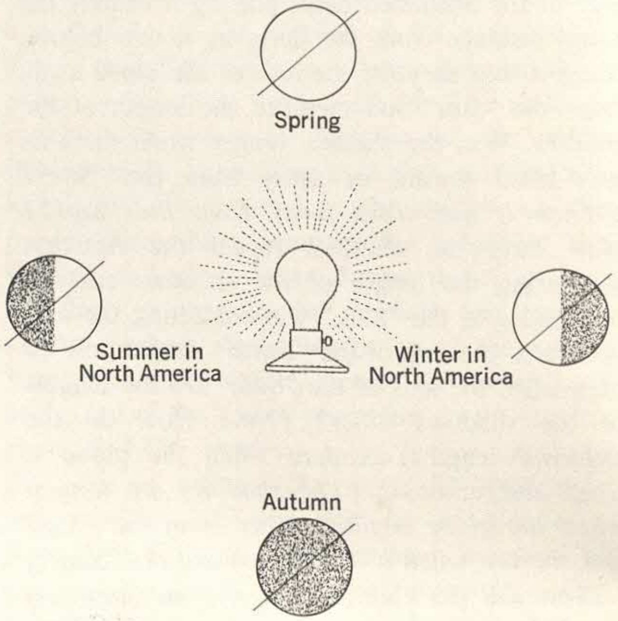
Unshaded lamp to represent the Sun
4 world globes (one will do if no more are available)
Modeling clay or masking tape

INTRODUCTION: One effect of the tilting of the Earth's axis is to cause seasons. Ask the children if they have noticed seasonal changes throughout the year. Have them list the seasons. What is it like during each of the seasons? What do they do differently at different times of the year? What are the months in each season?

Set the unshaded lamp on a table in the middle of the room. Darken the classroom. If four world globes are available, set them on the north, east, south, and west sides of the lamp and about 8 feet away. If four are not available, let the children stand and hold the globe consecutively in each position. Keep the Earth's axis pointed north at all times. A corner of the ceiling can serve as the North Star. Spin the globes in the correct direction and help the children notice how the "Sun's" light strikes the "Earth" differently at each position. Locate your position on the globe with a lump of clay or piece of masking tape. As each globe spins, help the children notice how much light strikes your location.

Ask the children, "In which position of the Earth's journey around the Sun does our city get the most Sun? The least Sun? In which position do we have winter? Summer? Autumn? Spring?"

Extending Ideas: Ask the children to construct a chart showing the position of the Earth in relation to the Sun at each season of the year. Have them find their position on the chart now. At which time of the year are the days short and the nights long? At which times of the year are the days equal in length? Let the children demonstrate why this is so. Each Monday, have them check in a local newspaper or almanac the times of sunset and sunrise. Suggest that they keep weekly records of the number of hours of darkness and daylight; they can make a line graph indicating the date, the month, the time of year, and the number of hours of sunlight. Have the class look up the words *equinox* and *solstice*. Help them find the location on the graph and the chart of the vernal and the autumnal equinoxes, the winter solstice and the summer solstice. See if the children can determine how the number of hours of sunlight affects the growing season in your locale. Ask some of the children to do research to find out



what other factors cause our seasons. Some children could also check in out-of-town newspapers or correspond with friends or relatives in other cities to determine the number of hours of darkness and light in their locale.

Learnings: The tilting of the Earth's axis affects the amount of sunlight striking the Earth as it travels around the Sun. This is partially responsible for the changing of the seasons.

ACTIVITY 17 (y,z)

DRAWING AN ELLIPSE

Purpose: To show the shape of the Earth's orbit

Concept to be developed: The path of the Earth around the Sun is an ellipse.

Materials needed:

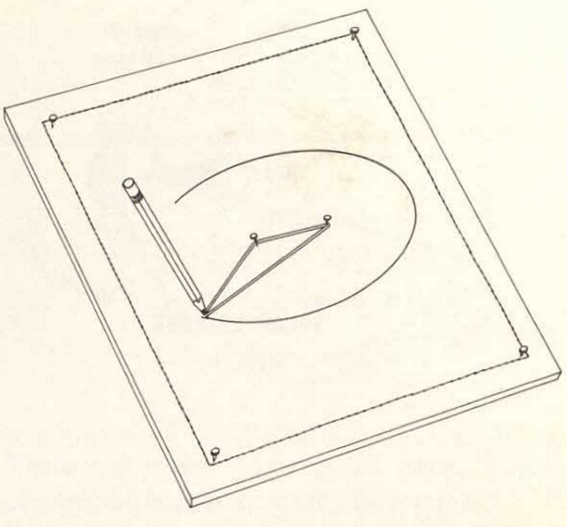
Large sheets of paper
Pins
Pinning board
Large drawing board or heavy tag board
String
Pencils

INTRODUCTION: Explain to the children that as the Earth travels around the Sun, its path is not a circle. The Earth is about 92 million miles away from the Sun during the winter and about 94 million miles away in the summer. Therefore, since the Earth's distance from the Sun changes, it cannot be traveling in a circle. The name of this path in which the Earth travels is an ellipse.

The orbits of the Earth, the Moon, and the other planets and their moons are ellipses. To help the children find out more about ellipses and how they differ from circles, have them pin a large piece of paper, about 18 inches by 24 inches, on the bulletin board or on a piece of heavy cardboard, with two pins near the middle of the paper, about 4 inches apart. Then have them tie string about 1 foot long into a loop, place the loop over the pins, and pull the string taut with a pencil. Ask them to draw a line, using the string to guide the pencil.

The result will be a true ellipse. Each pin represents a *focus* of the ellipse. Have the children draw several ellipses, varying the distances between the pins. What kind of figure is produced when the pins (foci) are right next to each other? *(A circle.)*

Learning: The path of the Earth around the Sun is an ellipse.



ACTIVITY 18 (y,z)

CAUSING AN ECLIPSE

Purpose: To demonstrate how eclipses occur

Concept to be developed: The motions of the Earth and the Moon can align them in such a way that their position relative to the Sun will cause an eclipse.

Materials needed:

Lamp
Tennis ball
String

INTRODUCTION: We know that the universe is in motion because we sometimes see the shadow of the Earth on the Moon and the Moon against the Sun as they travel through space. In both cases the light from the Sun is blocked, producing an eclipse. The children can see how an eclipse occurs by performing the following Activity.

With an unshaded electric lamp in the center of the classroom to represent the Sun, have several children sit in a ring around the light. Tie a tennis ball to a string to represent the Moon. Tell the class that each child's head represents the Earth. Have one child suspend the "Moon" in front of each child's eyes and move it around his head. Can the children determine which way the moon should revolve? *(The moon revolves in a counterclockwise direction.)* As the ball comes between the child's eyes and the electric lamp, part of the "Sun's" light is blocked, causing an "eclipse of the Sun." This is called a *solar eclipse*. Call the children's attention to the shape of the ball against the "Sun's" light. Have the child holding the "Sun" bring the ball behind the seated child's head. Now the "Moon" should be in the shadow of the

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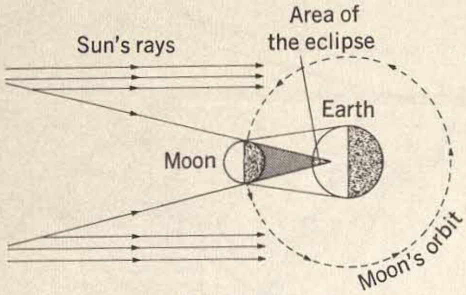
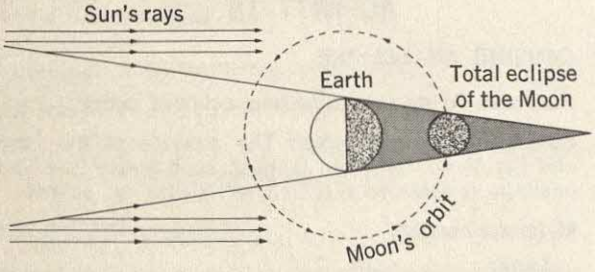


SOLAR ECLIPSE



LUNAR ECLIPSE

"Earth." Since there is no moonlight reflected to the "Earth," this is an "eclipse of the Moon." This is called a *lunar eclipse*.

Ask the children, "If the Moon goes around the Earth once each month, why don't we have an eclipse each month?" *(The orbit of the Moon is tilted at approximately a 5° angle and is therefore not always in a line between the Sun and the Earth.)* Repeat the Activity above. However, this time make the tennis ball revolve in a plane that is slightly tilted. Now, as the ball passes in front of the seated child, the "sunlight" will not always be blocked out. Sometimes it is blocked totally and other times only partially.

To help the children determine why we sometimes have total eclipses and other times have partial eclipses, bring the ball close to one child's eyes. Now move the ball closer to the lamp. Ask him to tell what he sees. When the ball is close to his eyes, it will probably block out all the light. When the ball is close to the electric light, he will probably see the ball with much light shining around it. This may help him to see what causes total and partial eclipses.

Extending Ideas: Some further questions which could be pursued might be: Why do total eclipses occur so rarely? Why are there more solar eclipses than lunar eclipses? Why don't solar eclipses occur everyplace on Earth at the same time?

Learnings: A solar eclipse occurs when the Moon passes between the Sun and the Earth, preventing some of the sunlight from reaching the Earth. A lunar eclipse occurs when the Earth passes between the Sun and the Moon, preventing some of the sunlight from reaching the Moon.

ACTIVITY 19 (y,z)

VIEWING AN ECLIPSE

Purpose: To instruct the children in the proper method of viewing an eclipse

Concept to be developed: It is unsafe to view an eclipse by looking directly at the Sun, for the bright light can damage a person's eyes.

Materials needed:

2 pieces of stiff cardboard

INTRODUCTION: Explain to the children that by observing eclipses, the time intervals in which they occur, and the shadows they cause, scientists have been able to gather some information about the shape, size, and motions of the Sun, Moon, and Earth. Ask the children if they can tell one way we have determined the shape of the Earth. Have them watch in newspapers or look in an almanac for the dates of eclipses. Plan to take the class outdoors when an eclipse occurs in your area. Do not, however, allow them to look directly at the eclipse, as damage may occur to their eyes. Even the use of smoked glass or several layers of exposed film over their eyes is not entirely safe. The following method of viewing an eclipse is considered to be safe.

One safe method of observing an eclipse is to view it indirectly. Have the children punch a hole through a piece of cardboard. After they have done so, ask them to turn their backs on the Sun and hold the cardboard over one shoulder to permit the Sun's image to shine through the hole onto a second piece of cardboard or paper held in front of them. Do not allow them to look at the Sun through the hole in the cardboard.

Learning: One safe way of viewing a solar eclipse is to observe it indirectly through a hole in a piece of cardboard.

ACTIVITY 20 (y,z)

BECOMING ACQUAINTED WITH THE NIGHT SKY

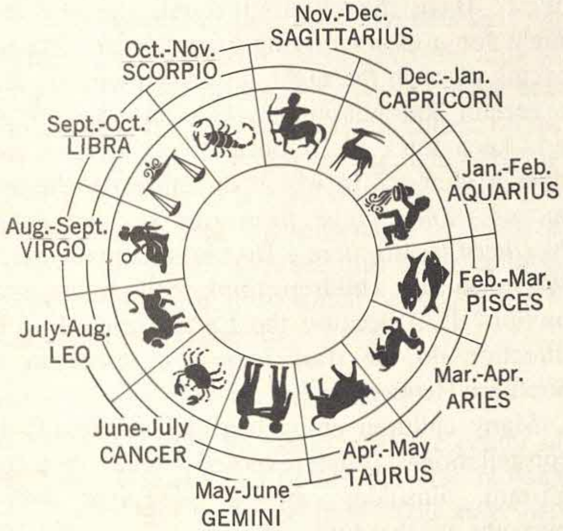
Purpose: To familiarize the children with the constellations

Concept to be developed: The Earth's movements cause apparent changes in the positions of stars.

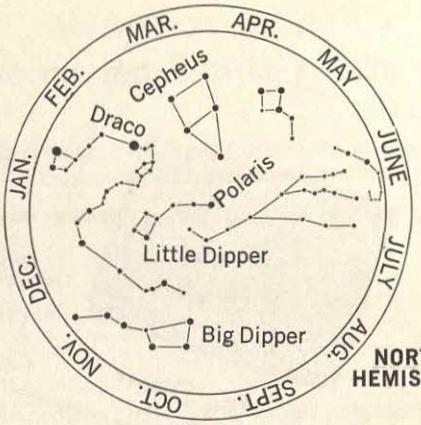
Materials needed:

Old lamp shade
Black and white paints
Black and white construction paper
Glue

INTRODUCTION: Explain to the children that another way by which we can tell that the Earth is in motion was discovered many years ago. It is believed that as the people of long ago gazed into the night sky and saw many stars, they imagined they saw outlines of many different objects and made up stories to go along with them. They saw kings and queens, and animals such as bears, fish, scorpions, and fierce dragons. You may want the children to read about some of these legends. The ancients also saw that some figures were always in the sky but in different positions, while others were seen only at certain times of the year. They noticed that the Sun seemed to rise each morning out of certain star-figures and to set each night into others. Throughout the year, the night sky would seem to change, until the Sun set and rose again in the same star-figure. Point out that today we call these figures constellations, and that those twelve constellations in which the Sun seems to rise and set are called the zodiac.



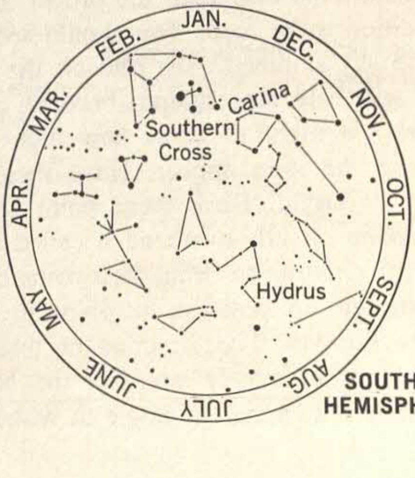
Obtain a star map (there is one in most books on astronomy). Help the children locate the more familiar constellations: the Big Dipper, the Little Dipper, Draco (the Dragon), etc. Are these always visible where you live? *(Yes.)*



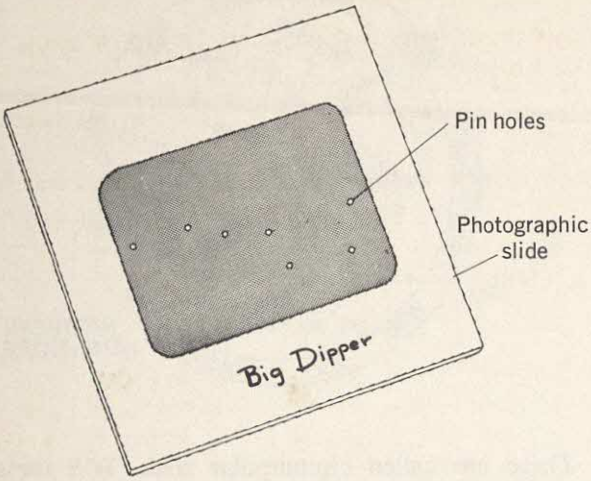
NORTHERN HEMISPHERE

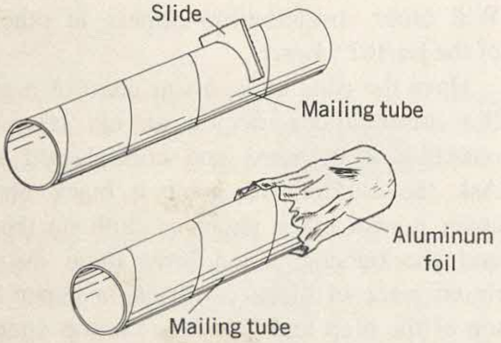
These are called circumpolar stars. Will these constellations appear south of the equator? *(No.)* Will other constellations appear in other parts of the Earth? *(Yes.)*

Have the class make a star chart as a guide to the constellations. Secure an old lamp shade; one that is flattened and cone-shaped is best. Ask the children to paint it black and then cover it with black paper or cloth on the inside and the outside. Then have them cut out a round piece of black construction paper for the top of the map and glue it to the top opening of the shade. Suggest that the children collect the little round pieces of paper left after using a paper punch to use as stars and, using these and white paint, form the various constellations on the inside of the shade. The circumpolar constellations should be placed on the paper that is fastened to the top of the shade and the other star groups on the sides of the shade. Have the children divide the lamp shade into twelve equal parts. Help them to determine which constellations can be seen in each month of the year. Suggest that the children take the com-



SOUTHERN HEMISPHERE





pleted star chart outdoors at night and, using a flashlight beam as a pointer, locate the stars in the sky from the map. To orient the map, it must be pointed at the North Star. Use a compass to locate north. To find the North Star (Polaris), look for the Little Dipper and the Big Dipper. The North Star is the star at the tip of the handle of the Little Dipper. Try to find it by extending an imaginary line through the two stars forming the outer edge of the Big Dipper. When the North Star is located, point the lamp shade–star map toward the North Star and rotate the map until the proper month is in a position to be read. You should see a picture in the sky similar to the one on the star map.

It will help the children become oriented to the sky at night to know how high above the horizon the stars appear. Have them look directly overhead. Have them point straight up. This point directly overhead is called the *zenith*. Ask the children to bring their arms down from the straight-up position to point to the north on the horizon. The direction of their pointing should approximately intercept the North Star. Can they determine the angle at which they are pointing toward the North Star? This should be equivalent to the number of degrees above the equator at which they are located.

Extending Ideas: Have the children give their ideas as to why some constellations are called circumpolar. *(Because they seem to travel around the pole star. They are always in the sky in the Northern Hemisphere.)* Have the children try to locate the circumpolar constellations on a star chart in an astronomy book. Encourage the children to watch the sky at various times of night and throughout the year. These questions might direct their observations: Which constellations or stars are directly overhead? Which are directly north on the horizon? South? East? West? Have the children watch the sky each night for a month, trying to notice any changes taking place in the night sky. Ask them to locate a certain constellation, such as the Big Dipper, and keep track of its position each night. How does it change? In which direction do the stars move? *(They move from east to west in the Northern Hemisphere.)* Do the stars really move? What do the children think causes the stars' motion? Is it because the Earth turns? In what direction do the stars appear to move in the Southern Hemisphere?

Many children enjoy learning to identify the constellations. Underexposed and discarded 35-mm. filmslides can be perforated with a pinpoint in the form of various constellations. The slides can be projected on a screen or in a viewer and the constellations identified. Or they can be dropped into a slot made in a mailing tube and held up to the light. The forms of certain constellations can be punched into heavy black construction paper or aluminum foil and placed over the end of the mailing tube and held to the light for identification. Use a separate piece of foil or paper for each constellation.

If some of the children have cameras, encourage them to take pictures of the night sky. Place the camera on the ground and set the shutter for a time exposure. Allow the shutter to remain open for an hour or more. The stars will appear on the photograph as curved lines rather than as separate dots. How does this help us see that the Earth is in motion? If there is an observatory or planetarium close by, take the class on a study trip to find out about the motions of the Earth and the universe. Possibly someone in the class or in the neighborhood owns a telescope. Encourage the children to utilize this tool to understand better the movements in space. Many communities have a sky-watchers club. Invite members of such a group to visit the class.

Learnings: The star directly over the axis of the Earth appears to be stationary. This is Polaris, the North Star. Other star groups appear to revolve around the North Star. This movement is apparent because of the Earth's movement.

Summing Up Ideas: In this section, the children were introduced to the two primary motions of the Earth, rotation and revolution. The Earth rotates around its axis; this rotation causes the alternating periods of light and darkness that we call night and day. The Earth revolves around the Sun; because the Earth's axis is tilted and because the path of its travel is an ellipse rather than a circle, the amount of sunlight striking the Earth's surface as it revolves varies. It is this variation that causes the seasons. The children were also introduced to solar and lunar eclipses and constellations, both of which help us to know that the Earth is in motion.

WHERE IS THE EARTH IN SPACE?

Man once explained his position as the center of everything, with the rest of the universe moving in relation to his central position. You may wish to have some children do research on the lives of Ptolemy and Copernicus and to report on the views these men had of the solar system. A discussion might be carried on as to their differing views. If so, have the children draw diagrams showing the way each of these early astronomers perceived the universe.

As new instruments were invented to explore the universe and the accuracy of measurement and the skill of tenacious observation increased, man came to the conclusion that the Earth is only a relatively tiny speck in a vast expanse of space. He determined that there are other planets, that the stars are other suns and, in some cases, bigger and brighter than our own, and that there are many more galaxies than our own Milky Way.

In the following Activities, the children will learn about the Earth's position in the solar system and how it compares with the other planets.

ACTIVITY 21 (x,y,z)

COMPARING THE DISTANCES OF PLANETS FROM THE SUN

Purpose: To locate the Earth's position in the solar system

Concept to be developed: The Earth is the third planet from the Sun.

Materials needed:

Tape measure
Paint
Stop watch

INTRODUCTION: Ask the children whether they know their addresses in the universe. Suggest that they know, of course, where their homes are, and that they live on the planet Earth. Children like to "play" with this concept by listing their addresses as: Planet Earth, Solar System, Milky Way Galaxy, Universe.

There are nine known planets in the solar system. Have the children look in a book on planets and the solar system to find the distance of each planet from the Sun. Discuss with them what would make a logical and usable scale of miles so that proportionate distances could be measured on the schoolyard. In the following table of distances, 1 inch equals 1 million miles.

Measure these distances away from a central, open spot and mark the position where each planet would be. Have a child stand on the point designating each planet to get an idea of that planet's location. Can the children align themselves in their proper order from the Sun? Let another child serve as the Sun. Have the children walk around the "Sun," keeping in their orbits. How long does it take for "Mercury" to go around the "Sun"? For the "Earth"? For "Neptune"? For "Pluto"? Using a stopwatch, one child can record the time it takes for each "planet" to revolve around the "Sun." The chil-

Planet (arranged in order from the Sun)	Approximate distance from the Sun (millions of miles)	Distance on the schoolyard (feet)
Mercury	36	3
Venus	67	6
Earth	93	8
Mars	141	12
Jupiter	483	41
Saturn	886	74
Uranus	1783	149
Neptune	2792	232
Pluto	3666	309

dren should find out that the farther the planet is from the Sun, the longer it takes to make a complete revolution.

Learnings: There are nine known planets revolving around the Sun. Earth is the third planet.

ACTIVITY 22 (x,y,z)

COMPARING THE SIZES OF THE PLANETS

Purpose: To show that the Earth is a relatively small planet

Concept to be developed: The planets differ in size.

Materials needed:

9 balls of various sizes

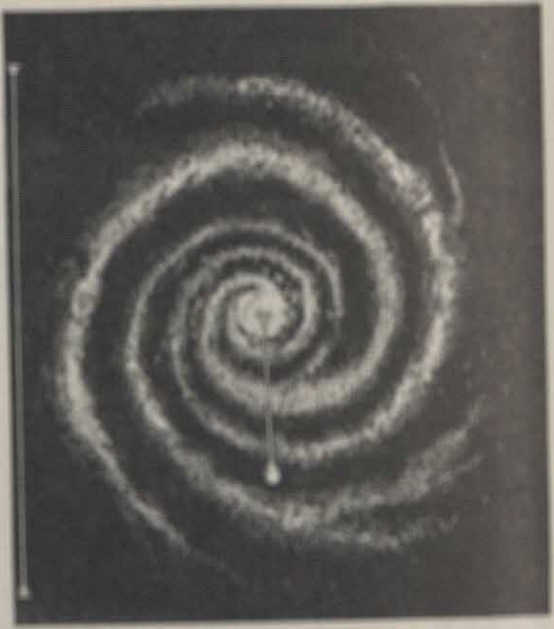
If the Sun were about the size of an average classroom, the rest of the planets would be about these sizes:

Mercury—marble
Venus—tennis ball
Earth—tennis ball
Mars—Ping-pong ball
Jupiter—basketball
Saturn—volleyball
Uranus—baseball
Neptune—baseball
Pluto—marble

Have the children set these various balls and marbles into the positions they occupy in the solar system and label each. Discuss with the class which member of our solar system is largest. What other planet is about the same size as the planet Venus? Why do such huge objects as the Sun appear small from far away? *(The farther away an object is, the smaller it appears.)*

Extending Ideas: Have the children take an imaginary trip through space. In planning for their trip, discuss such questions as: Which object would you come to first, that is, what other natural space body is closest to the Earth? *(The Moon.)* Take a "ride" to the closest planet. Which one would that be? *(Venus.)* If you traveled at 25,000 miles per hour, how long would it take you to get to the Moon? *(If it is 240,000 miles away, it would take about 10 hours.)* It would take about 1,900 hours to get to Mars at that speed. How long would it take to get to Alpha Centauri, which is approximately 4.3 light-years away? *(About* 10.3×10^8 *hours, or almost 125,000 years.)*

The children should now be able to understand the idea that our Sun is only one star among 100 million or more stars that make up the Milky Way galaxy. Explain to them that astronomers believe that the Milky Way galaxy is one of millions of galaxies. Our Sun is about 25,000 light-years from the center of the galaxy. At night we can see the Milky Way as a path of stars through the sky. When we look at it, we are looking toward the plane of a gigantic wheel that is about 100,000 light-years across. The children will probably comment on their own that the Earth is very small in comparison to this vast distance.



Learning: The Earth is a comparatively small planet.

Summing Up Ideas: In this section, the children were introduced to a number of ideas about the Earth. They learned that it is the third planet from the Sun and that it is only one of nine planets that orbit the Sun. In addition, they learned that the Earth is a relatively small planet and that space is vast.

IMPORTANT IDEAS IN THIS CHAPTER

For the kindergarten, primary, and intermediate grade children, the ideas with the most meaning and application are:

- All objects occupy space.
- Space is all around us.
- Stars that are close to Earth seem brighter than those that are farther away.
- The Earth is in motion.
- The Earth rotates on its axis.
- Day and night are caused by the rotation of the Earth.
- The Earth revolves around the Sun.
- The Earth's axis is tilted.
- The tilting of the Earth's axis contributes to the change of the seasons.
- The stars appear to change their positions because of the Earth's motion.
- There are nine planets circling the Sun.
- Earth is the third planet from the Sun.
- The Earth is a comparatively small planet.

In the intermediate and upper grades, the children should be led to develop concepts that are more quantitative and complex:

- A light-year is the distance that light travels in one year, almost 6 trillion miles.
- Triangulation is one of the ways in which astronomers measure distances.
- Parallax is the apparent change of position, against a stationary background, of an object sighted from two different positions.
- The apparent path of the Sun's movement is called the ecliptic.
- The path of the Earth around the Sun is an ellipse.
- A solar eclipse occurs when the Moon passes between the Sun and the Earth, preventing some of the sunlight from reaching the Earth.
- A lunar eclipse occurs when the Earth passes between the Sun and the Moon, preventing some of the sunlight from reaching the Moon.

Let a bright electric lamp represent the Sun. Have the children compare the brightness of the light in a darkened room and in a well-lighted room. Take the lamp out of doors during a sunny day. Does it look as bright as it did in the classroom? *(No.)* Have one child view the lamp from across the schoolyard. Does it look as bright from a great distance? *(No.)* Then hold a flashlight next to the bright lamp. Is the flashlight beam clearly distinguishable next to the bright lamp? *(No.)* What happens to the stars during the day? Do they still shine? *(Yes.)* Why don't we see them? *(Their light is obscured by the brighter light of the Sun.)*

Learnings: We do not see the stars during the daylight hours because their light is obscured by the brightness of the Sun's light. The Sun's light appears so much brighter because the Sun is much nearer the Earth.

ACTIVITY 25 (y,z)

USING BINOCULARS AND TELESCOPES

Purpose: To find out how telescopes are used to help us see into space

Concept to be developed: Binoculars and telescopes help us to see faraway objects by making them appear closer and larger.

Materials needed:

Binoculars
Telescopes
Opera glasses
Field glasses

INTRODUCTION: Discuss with the children what they observe in the night sky. What do they notice about the stars and planets? Can they tell how far away the stars are by using just their eyes? Can they notice any larger or smaller stars by using just their eyes? Can they suggest some things that might aid their eyes in observing objects in space?

What tools that use light energy can help our eyes see objects in space? Our eyes are valuable and powerful tools to help us see into space. However, some objects in space are so small—such as man-made satellites; or are so far away—such as the distant stars; or are so faint—such as the distant planets—that our eyes sometimes need help to gather the light energy coming from them.

Have the children bring binoculars, field glasses, opera glasses, or telescopes to school. Care should be taken with these instruments, as they are sometimes delicate and expensive. Help the children practice looking at various objects in the sky. Do the "tools" help their eyes to see distant objects clearly? How can they tell if the binoculars help us to see? Have each child try several different binoculars, telescopes, opera glasses, and field glasses. Do they seem to bring objects closer or make them seem bigger? Objects in space should be seen more clearly with the aid of these tools.

Next have the children look across the schoolyard at a row of fence posts, trees, or children standing in line without the observer's turning his head from side to side. How many can they count? Now let the children hold a pair of glasses or a telescope to their eyes and look again at the row of objects. Is there a difference? *(Yes.)* Can they see as many? *(No.)* Do those which they see seem larger? *(Yes.)* Can they pick out individual qualities better? *(Yes. They can see knots on a tree, buttons on the children's clothes, etc.)*

Give the children a chance to become well acquainted with the use of binoculars, glasses, and telescopes. Lead them to generalize that telescopes and similar optical tools make it possible to observe more widely and more accurately. Help the children see that telescopes and binoculars or glasses are different, that some are more powerful than others. Have them look through many different telescopes, glasses, and binoculars and determine which make objects look largest and which make objects seem closest.

Extending Ideas: Encourage the children to look at the Moon through binoculars, glasses, and telescopes. Can they see the craters? *(Possibly, if the instruments are powerful enough.)* Have them look for the planets. Can they see the moons of Jupiter? Can they see the color of Mars? Ask them to look at the stars. Can they distinguish double stars? Can they see the color of certain stars, such as Antares? *(Consult a star map.)* Encourage the children to practice observing satellites. Some of the larger man-made satellites, such as the Echo satellite, are often visible. Newspapers often list when these will pass over your location. Have the children prepare to observe them through binoculars, glasses, or telescopes when they pass overhead. To practice observing a moving object, the children may develop skill by observing airplanes as they pass overhead. Help the children to keep looking at the airplane while bringing the binoculars up to their eyes. If they look down to find their glasses, they may lose sight of the fast-moving object.

Learning: Telescopic devices make objects seem larger and closer.

ACTIVITY 26 (x,y,z)

EXAMINING LENSES

Purpose: To find out how the lenses in telescopic devices work

Concept to be developed: Some lenses make objects appear larger.

Materials needed:

- Magnifying glasses
- Newspapers
- Medicine dropper
- Waxed paper
- Round bottles
- Eyeglasses

INTRODUCTION: Their work with binoculars, glasses, and telescopes in the preceding Activity should encourage the children to inquire how these work. What makes them cause objects to appear larger? How much larger do the objects seem? What kinds of telescopes are there? How are they put together? Do larger telescopes cause objects to appear larger than they do when seen through smaller telescopes? There are several types of telescopes. Perhaps your school has one, or there may be one available to you through a parent, club, university, or college. The children may better understand how a telescope works if they have many opportunities to handle and manipulate various kinds of lenses.

Can the children discover on their own the shape a glass or other transparent object must have in order to be a magnifying device?

Place a small square of waxed paper on top of a piece of newspaper. Use the medicine dropper to place a small drop of water on the waxed paper. Have the children look through the drop of water at the print of the newspaper. How does the newspaper appear? Does the print look larger? *(Yes.)* Have the children describe the shape of the drop of water. *(It is rounded.)* Ask the children what we call devices that magnify images. *(Lenses.)* The drop of water in this case acted as a lens to magnify the newsprint.

Help the children find other examples of lenses—round bottles, eyeglasses, curved windshields. Let them examine the shape of a lens from a simple magnifying glass. What shape is it? *(Rounded.)* Can the children find some common characteristic of all these items that causes them to magnify? *(The curvature of the surface of the water, the windshield, the lens in the eyeglass, and the bottles causes them all to become magnifiers).*

Learnings: Curved objects tend to act as magnifiers. An object that acts as a magnifier is called a lens.

ACTIVITY 27 (y,z)

DETERMINING THE POWER OF A MAGNIFIER

Purpose: To find out how the magnification of a lens is measured

Concept to be developed: The magnification of a lens is the number of times it increases the size of an object.

Materials needed:

- Various magnifying glasses, reading glasses, hand lenses, etc.
- Newspaper

INTRODUCTION: Ask the children if the magnifiers they worked with in the preceding Activity all increased the size of the object being viewed by the same amount. Point out that not all lenses magnify objects equally. Tell them that we call the power of a lens its magnification. The next Activity will enable them to measure the power of a lens.

To find which shape of magnifier has the most power, the children can look at a newspaper or printed page through a number of magnifiers of different shapes. Have them lay each magnifier on the newspaper and count the number of lines within the rim of the magnifier. Now ask them to lift the magnifier until the print comes into focus and count the lines again. Is the number of lines greater or smaller than when the lens is lying on the paper? *(Smaller.)* Can the children determine how much the lens magnifies? If there are 20 lines covered when the lens is on the paper and only 10 lines when it is in focus, then the lens makes the print look twice as big. Therefore, what is its power? *(Two times.)* The children can learn a rule or formula for this.

$$\text{Magnification} = \frac{\text{What is actually seen}}{\text{What is seen through magnifier}}$$

$$\text{Magnification} = \frac{\text{20 lines}}{\text{10 lines}}$$

$$\text{Magnification} = \text{2 times}$$

Learning: The power, or magnification, of a lens is the number of times it increases the size of an object.

ACTIVITY 28 (y,z)

FINDING THE FOCAL LENGTH OF A LENS

Purpose: To learn that the focal lengths of lenses differ

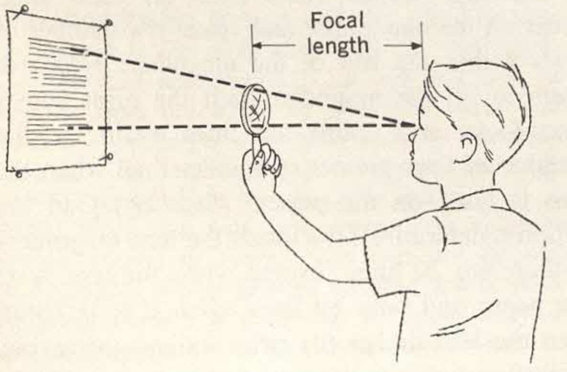
Concept to be developed: The focal length of a lens is the distance from the center of the lens to the point at which the rays of light passing through the lens converge.

Materials needed:

Lenses of various shapes
Candle or lamp
Ruler
Piece of white paper pinned to a board
Newspaper

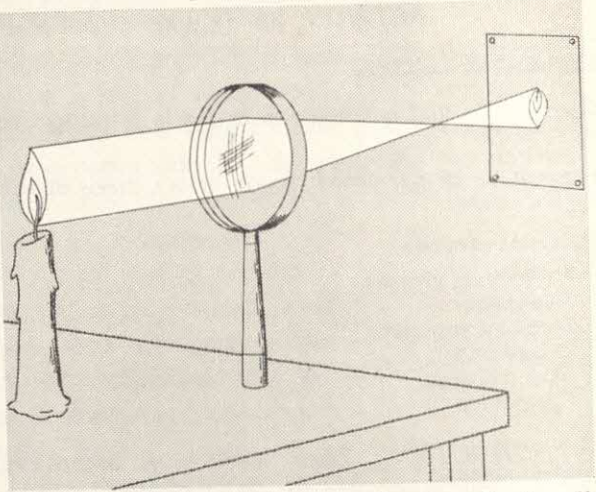
INTRODUCTION: In the preceding Activity, the children may have noticed that the various lenses were in focus (that is, gave a clear image) at different heights above the newspaper. Ask the children if they can explain why. Then introduce the focal length. Tell the children that the focal length of a lens is the distance between the center of the lens and the observer when the object is in focus. Then proceed with the following Activity, having the children find the focal lengths of different lenses.

To find the focal length of a lens, have a child hold the magnifier so that the print of the newspaper is in sharp focus. With a ruler, measure the distance from his eye to the magnifier. This distance is called the *focal length.*



Have the children try several different lenses to find the focal length of each.

Another way to find the focal length is to pin a piece of white paper on a board. Place a lamp or lighted candle on a nearby table. Darken the room and hold the magnifier between the paper and the candle. Move the magnifier back and forth until a sharp image of the flame is obtained on the paper. Then measure the focal length. Ask the children, "How does the image appear now? Is it larger or smaller than the candle?" *(Smaller.)* "Why is it upside down?" *(As shown in the illustration, the light rays cross to invert the image.)**



Learning: The focal length of a lens is the distance from the center of the lens to the point where the rays of light passing through the lens cross.

ACTIVITY 29 (z)

DISCOVERING THE PRINCIPLE OF THE TELESCOPE

Purpose: To find out how a telescope works

Concept to be developed: A refracting telescope uses two lenses, one with a long focal length (the objective lens) and one with a short focal length (the eyepiece lens).

Materials needed:

Several hand lenses or magnifiers of varying sizes, some very small and some very large
Candle
Piece of white paper pinned on a board
Ruler

INTRODUCTION: Ask the children if they can think of what instrument an astronomer uses to study the stars. (A telescope.) *There are several types of telescopes that are used. One of these is the refracting telescope.*

Have a child take a large magnifier and a small magnifier. Ask him to hold the large one

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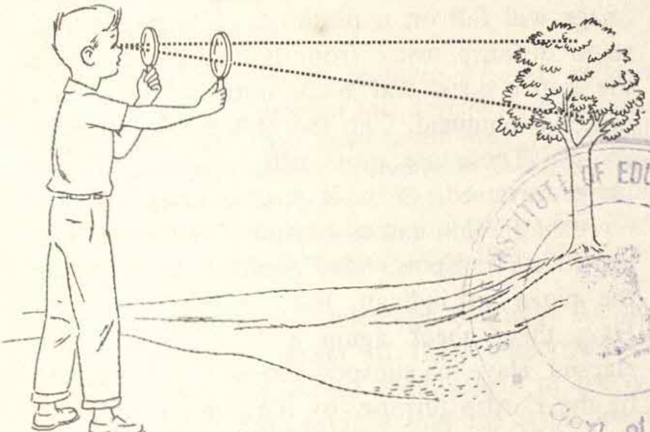
*For a more thorough discussion of lenses, see *Energy in Waves*, by Louis Cox (Investigating Science with Children Series; Darien, Conn., Teachers Publishing Corporation, 1964).

at arm's length and the small one about an inch from his eye. Let him look across the room or schoolyard at an object. Have him move both magnifiers until the object comes into focus. Ask him to describe what he sees. Then measure the focal length of each lens.



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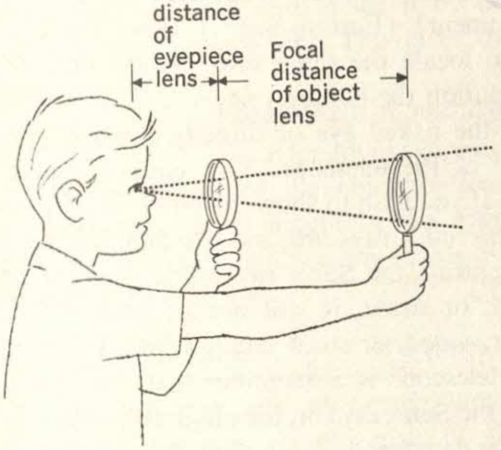
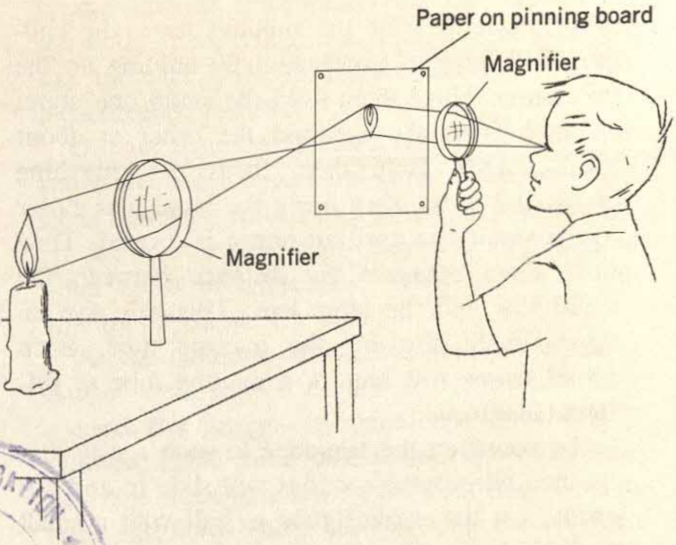

Focal distance of eyepiece lens
Focal distance of object lens

Help the children discover that when they look through lenses, distant objects appear smaller and inverted. The stars are so far away that they appear as mere points of light. Does it matter if they appear upside down? *(No.)* Objects like the Sun, Moon, and planets are close enough to be seen clearly. Does it matter if these appear upside down? *(No.)* Ask the children, "If a lens makes distant objects appear smaller, what is the advantage of using it?" *(To bring the distant object's image close to us.)* Explain to the children that a simple telescope uses two lenses. The first lens takes the light from space, bends it so that the image is reduced in size, and places the image in front of our eyes where we can examine it with another magnifier, just as we did the print of the newspaper.



Then set up the candle, magnifier, and paper, as shown in the illustration. Have the children examine the image of the candle with another lens as shown. Ask the children, "How does it appear?" *(The image is large but upside down.)*

Learning: In a telescope, one lens forms an image at a point in front of our eyes, where we can look at it through another lens.

ACTIVITY 30 (y,z)

CONSTRUCTING A TELESCOPE

Purpose: To construct a simple telescope

Concept to be developed: A simple refracting telescope has two lenses, one with a long focal length (the objective lens) and one with a short focal length (the eyepiece lens).

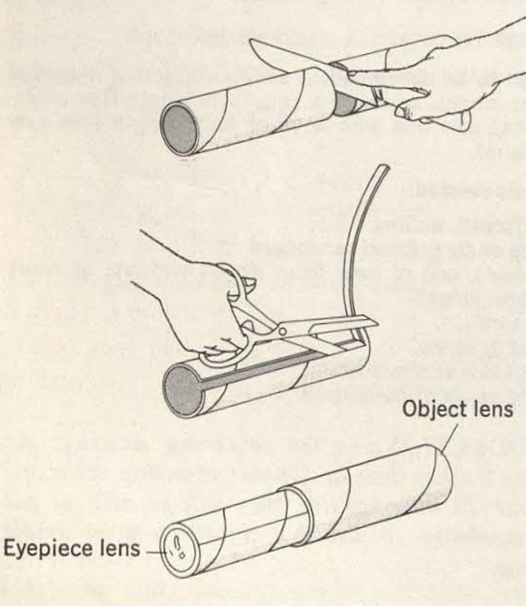
Materials needed:

- Cardboard mailing tube
- Piece of corrugated cardboard
- 2 lenses, one of long focal length and one of short focal length
- Scissors
- Wood or straw
- Small saw or sharp knife
- White paper or cardboard

INTRODUCTION: In the preceding Activity, the children learned how a simple refracting telescope functions. In this Activity, they will be able to put this knowledge to use by constructing a simple telescope.

A simple telescope may be constructed by placing two lenses inside a telescoping mailing tube. The *objective lens* should have a focal length of about 8 inches and the *eyepiece lens* a focal length of about 1 inch. To determine the appropriate length for the mailing tube, the children will have to experiment by holding up the two lenses. Have them hold the small one about ½ inch from the eye and the other at about arm's length. Help them focus on something across the room, then bring the large lens closer to the small one until an image is formed. Then have them measure the distance between the small lens and the large lens. This will give an approximate size for the mailing tube. Each set of lenses will require a mailing tube of different length.

To construct the telescope in such a way that the two telescoping sections will slide in and out easily, cut the mailing tube in half with a small saw blade or sharp knife. Using the scissors, remove a ¼-inch section from the length of the tube so that its diameter will be smaller than that of the other half. Wrap several turns of masking tape around the narrower of the halves of the mailing tube to make it strong. The two sections should now be of such a size that one slides easily into the other. The lenses can be held in place by cutting out two rings of corrugated cardboard and taping a lens in the center of each. Insert them into the ends of the mailing tube.



Have the children look through the telescope. Ask them to move the two sections in and out until a sharp image is in view. Let them look at objects across the schoolyard and at the Moon.

So that they can get a picture of the Sun with a telescope, have the children use the telescope to project the Sun's light onto a piece of white paper. (Most telescopes have a special filter adaptation for the eyepiece to stop most of the Sun's bright light. Perhaps you can borrow a filter that will fit the telescope you made.) If the children point the telescope at the Sun, the image will fall on a piece of white paper held some distance away from the eyepiece. Move the paper back and forth until a satisfactory image is obtained. Can the children locate sunspots? (These are quite often visible.) Is the image reversed, or is it a true image? *(It is reversed.)* What causes sunspots? If the children can locate sunspots, have them make marks on the paper to indicate the sunspots' positions. Have them check again after some time has elapsed. Have the sunspots moved? Is this caused by the Earth's turning, by the Sun's turning, or by both? *(By both.)* What was the direction of movement? *(East to west.)* Have the children try to locate the same sunspots the next day.

Caution the children never to look at the Sun with the naked eye or directly through the eyepiece of the telescope. This could cause blindness. If you wish to show the children how powerful the Sun's rays are, use a magnifying glass to concentrate the Sun's rays on a piece of paper, wood, or straw. It will not be long before the paper, wood, or straw catches fire. The eyepiece of a telescope is a magnifier that would concentrate the Sun's rays on the children's eyes, causing similar damage.

Extending Ideas: Locate a telescope in your community; perhaps your school district, a high school, an observatory, or an amateur astronomer can be of help. Arrange for the children to observe the Moon, planets, and stars through a telescope. Ask them if they can see the craters on the Moon. Can they locate Mars? Can they see a star more clearly than they could with the telescope they made? Can they see more stars? Can they see any double stars?

Learning: A refracting telescope has two lenses, one with a long focal length (the objective lens) and one with a short focal length (the eyepiece lens).

ACTIVITY 31 (y,z)

DETERMINING THE MAGNIFICATION OF A TELESCOPE

Purpose: To determine the power of a refracting telescope

Concept to be developed: The magnification of a refracting telescope is the ratio of the focal length of its objective lens to the focal length of its eyepiece lens.

Materials needed:

Pencil and paper

INTRODUCTION: In Activity 27, the children learned how to determine the magnification of a lens. Now that they have constructed their own simple telescopes, they may be interested in finding out how to determine its power. Ask them to suggest a means of determining their telescopes' magnification. Then use the following Activity to show them how.

How much will a telescope magnify? To find the magnifying power of their telescopes, the children must know the focal length of the two lenses. Have the children find the focal length of the objective lens and divide it by the focal length of the eyepiece lens. This gives them the magnification.

$$\text{Magnification} = \frac{\text{Focal length of objective lens}}{\text{Focal length of eyepiece lens}}$$

If the focal length of the objective lens is 50 inches and the focal length of the eyepiece is 0.5 inch, then the magnification equals 50 inches divided by 0.5 inch, or

$$\text{magnification} = \frac{50}{.5} = 100 \text{ times.}$$

Ask them to compute the magnifying power of a telescope with an objective of 600-inch focal length and an eyepiece of ½-inch focal length. *(The magnification is 1,200 times.)*

You will probably find that although the Moon's craters can more easily be seen and the moons of Jupiter can be located, the view of a star is relatively unchanged. A telescope merely makes the pinpoint of starlight appear as a brighter pinpoint.

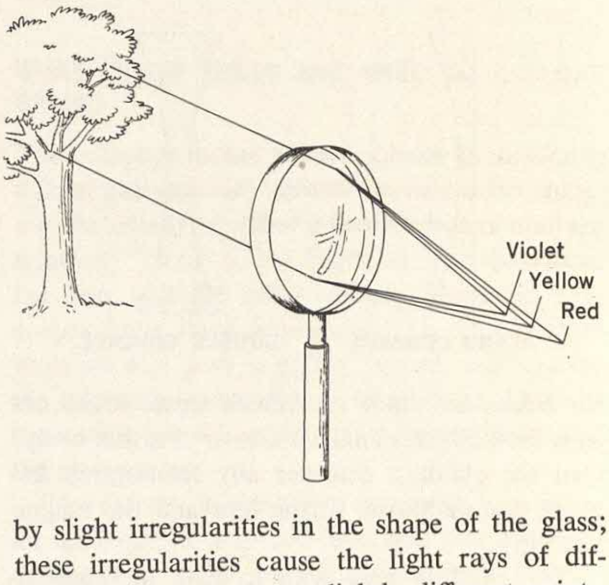
Extending Ideas: Individual children might report on how the following people contributed to the development of the telescope:

James Gregory	Galileo	Hans Lippershey
Isaac Newton	John Dollond	William Herschel

Have the class collect photographs of the Moon, stars, other planets, and the Sun. Some photos include information on the size of the telescope used. Have the children note which size telescope gives the largest, clearest, sharpest, most detailed picture.

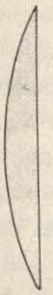
Discuss with the children how they could improve their telescopes. Could they add more lenses to increase magnification? Could they use different kinds of lenses? Can they find diagrams of other kinds of telescopes? What are some advantages of each?

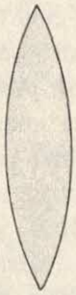
As the children use various lenses, they may notice some purple or red or yellow coloring around the image—it sometimes looks like a rainbow. Have them look at the edge of a white envelope through a lens, slowly moving the lens back and forth and sideways. Can the children find some "extra rainbow colors" through the lens? Explain that this extra color seriously hampers the work of the astronomer. It is caused by slight irregularities in the shape of the glass; these irregularities cause the light rays of different colors to focus at slightly different points. This is called *chromatic aberration.* There are several ways to correct this. One way is to increase the focal distance of the objective lens. What would increasing the focal distance do to the size of the telescope? *(It makes it so long it becomes unwieldy. One telescope was actually built that was 300 feet in length.)* Another way to correct chromatic aberration is to use another type of lens, the plano-convex lens, immediately behind the objective lens. It is usually made of flint glass, while the objective lens is made of crown glass. Flint glass is harder than crown glass and therefore causes the light rays to bend

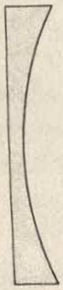


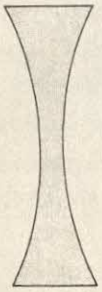
in a slightly different way. When these two lenses are used together, the effect is a longer focal distance; the difference in glass makes all the light focus at one point.

Have the children explore the shapes of lenses and try various combinations of lenses. What effect do they have? What is the focal length of each? Have the children try to find out what the lenses are made of Which lenses make objects look larger? Smaller? Closer? Farther away? Can the children discover any relationship between the curvature of the lens and the magnification?


PLANO CONVEX


DOUBLE CONVEX

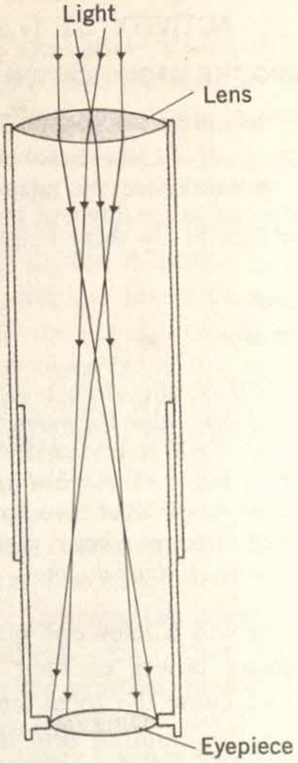

PLANO CONCAVE


DOUBLE CONCAVE

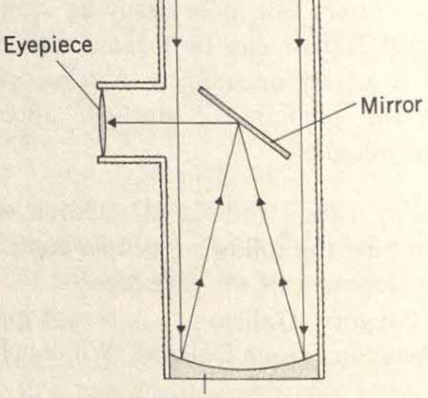
The children may wish to look in books to find different kinds of telescopes and the principles on which they operate. Perhaps some children may wish to draw diagrams of how the light is collected, focused, and viewed in each type of telescope.

(Refracting telescopes gather light by means of an objective lens at the front end of the tube. The objective brings the light rays to a focus part way down the tube. The eyepiece magnifies the image formed at this point.

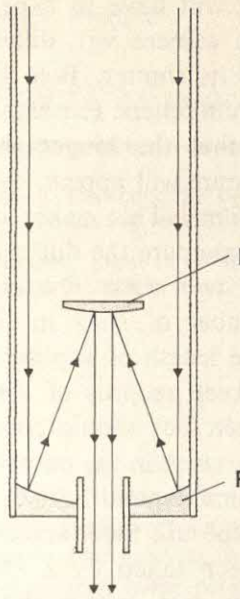
The Newtonian reflector gathers light by means of a curved mirror at the bottom of the tube. The mirror directs the light rays onto a second mirror that is tilted within the tube. An eyepiece at the side brings the rays to a focus and magnifies the image. Kits for constructing a reflecting telescope can be obtained from optical or scientific supply houses. They contain the tools and materials for grinding a concave mirror, including a glass disk called the "flat," which is to be ground into shape. The Cassegrainian reflector differs from the Newtonian reflector by having the eyepiece behind a perforation in the curved mirror.)



REFRACTING TELESCOPE



NEWTONIAN REFLECTOR



CASSEGRAINIAN REFLECTOR

Some children may wish to find out about the Schmidt camera telescope, which employs photographic film to collect the light. Another type of telescope used to view the Sun is called a tower telescope.

Ask the children to collect pictures of the world's famous telescopes, such as those at Mt. Wilson, Mt. Palomar, and other observatories. For what purposes is each used? What are the advantages and disadvantages of each? Encourage the children to collect pictures of stars and galaxies taken through each of the telescopes.

Have the children try to find out the sizes of the various telescopes. *(The Hale telescope has a mirror 200 inches in diameter. The largest refracting telescope is at Yerkes Observatory and is 40 inches in diameter.)* Encourage the children to speculate as to why observatory telescopes must be so big. *(One quality of a telescope is its ability to gather light energy. The size of the objective lens determines its ability to gather light.)* Ask the children which would have better light-gathering ability, a 50-inch telescope or a 10-inch telescope. *(The 50-inch telescope.)* Why? *(The power to gather light is proportional to the square of the diameter of the objective. Therefore, a star seen through the 50-inch lens would appear 25 times brighter than through a 10-inch telescope:*

$$\frac{50^2}{10^2} = \frac{2{,}500}{100} = 25.)$$

Have the children compare the relative light-gathering powers of the major telescopes that they have located. Let them consult an almanac to find more names, sizes, and locations.

Learning: The magnification of a refracting telescope is found by dividing the focal length of the objective lens by the focal length of the eyepiece lens.

Summing Up Ideas: In this section, the children were introduced to the primary instrument for astronomical observation, the telescope. They learned that telescopes gather light rays, which are a form of electromagnetic radiation. They learned about lenses and other types of magnifiers. In addition, they learned how telescopes are constructed, how to measure the power of telescopes, and how to build a telescope of their own.

WHAT OTHER TOOLS ARE USED TO EXPLORE SPACE?

The telescope assists the astronomer in analyzing distant galaxies and nebulas as well as in studying the details of other celestial objects that are relatively "close" to the Earth, such as the Moon, the Sun, and the other planets. However, telescopes have their limitations. Therefore, other tools are also used to gather, record, and analyze the information reaching us from space. Three of these tools are the camera, the spectroscope, and the photoelectric cell.

The camera is sometimes mounted on a regular telescope or a special telescope that has been designed to make use of the camera. Indeed, most of the study of the stars is done with photographic film. The use of film helps to detect star movement; in addition, the photograph provides a permanent record of observations.

The spectroscope is an instrument that breaks light into its component colors. Since different materials emit light of different colors when they are heated, the spectroscope is used to identify the components of planetary atmospheres and stars.

The photoelectric cell converts light energy into electric energy. By means of this device, the intensity of the light coming to the Earth from distant sources can be measured.

ACTIVITY 32 (y,z)

OBSERVING THE STARS WITH A CAMERA

Purpose: To show how astronomers can use cameras in their exploration of the heavens

Concept to be developed: Photographs provide a permanent record of observations.

Materials needed:

Camera
Film
Tripod

INTRODUCTION: Explain to the children that there are, of course, various other tools besides the telescope that aid man in studying space. Encourage their ideas about what these might be. Point out that telescopes have their limitations, since they can "see" only objects and phenomena relatively "close" to the Earth, and there is no way of recording the image seen through the telescope for later study. Introduce the idea that a camera may be combined with a telescope to make a permanent record on photographic film of what can be seen in space.

If the children have cameras, suggest that they try taking a time exposure of the stars to observe star movements. Help the children locate the North Star and have them aim their cameras at it. A camera on a tripod is preferable. (If a tripod is not available, place the camera on a table or chair.) Set the shutter speed for a time exposure. The surroundings must be dark, of course. A clear, moonless night is preferable. Allow the camera shutter to remain open for varying amounts of time from 20 minutes to several hours. What are the results? *(The stars appear as arcs on the picture.)* How will a photo taken straight up be different from a photo taken toward the North Star? *(The arcs in the photo taken toward the North Star will be moving around one unmoving star—Polaris. In the other photo, all the stars will be in motion.)* What causes this? *(The Earth's rotation.)* Can anything else be seen in the photograph? *(Possibly meteor or satellite trails.)*

Time exposure photographs of the Sun may be taken through dark filters. Some children may wish to try taking star pictures by using red and blue filters. What results are obtained? *(Some of the brighter stars now seem dimmer.)* Why? *(The filters cut out part of their light.)*

Explain to the children that film helps to detect the brightness of stars. Suggest that they expose their films for varying lengths of time. The children will have to experiment with this because each camera will differ, depending on the speed of its shutter. Box-type cameras will take longer than others. Explain that astronomers have found that the longer the exposure, the brighter the stars will appear. Why? *(More light reaches the film.)* This makes it possible to determine and compare the difference in brightness between any two stars. The children may find that the number of stars in their pictures increases as the length of exposure time increases. Have them keep records of the length of each exposure. Then they should compare each photo to find the variance in the number of stars, in the size of their images, and in their apparent brightness as the exposure time increases. When a time photo has been taken by a stationary camera, star trails are seen, rather than brighter stars. How do astronomers compensate for this? *(Telescopes with cameras attached are mounted on a clock drive so that they turn at the same rate as the Earth. They can therefore be trained on one point in space.)*

Extending Ideas: Have the children summarize their findings by listing reasons why a photograph is a valuable tool. Some of them might enjoy investigating why a photograph can detect stars that are less than 1/6 as bright as the faintest star visible. *(This is due to the chemicals on the film, which continue to react to the star's light as long as the film is exposed. Therefore, the longer a film is exposed, the more light is gathered.)* The children should realize that photographs, then, can give us brighter, more detailed pictures, and that a photograph is also a permanent record of the position and brightness of stars in relation to other stars. Therefore, by comparing pictures over periods of time, astronomers can detect changes. Also, through the use of special filters and processes, particular star colors can be detected. Photographs can be studied at any time, whereas a telescope must be used at night.

Learnings: When a camera is pointed toward the night sky and a time exposure is taken, the stars appear as arcs of light; these are called "star trails." Star movements on photographs are caused by the rotation of the Earth. A photograph provides a permanent record of observations.

Photographs are useful for measuring the comparative brightnesses of stars.

ACTIVITY 33 (x,y)

MEASURING WAVELENGTHS*

Purpose: To establish the concept of light's being composed of waves of differing length

Concept to be developed: Light is composed of waves of differing lengths; each color is a wave of a different length.

Materials needed:

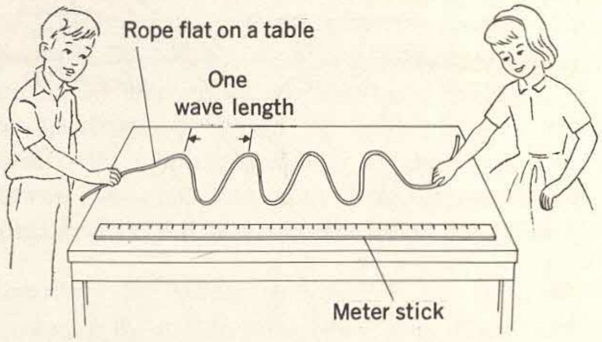
Jump rope
Meter stick

INTRODUCTION: Recall with the children their discovering some lenses that produced extra "rainbow colors" as they looked at objects (chromatic aberration). Ask the children what colors they saw. Where else have they seen these colors? Have they ever noticed them when light is reflected off the beveled edge of a mirror? Have they noticed the colors in the crystals of a chandelier? Have they ever seen a rainbow? What colors do they see? Where do these colors come from? Explain to the children that the light that comes to our eyes from the Sun and the stars can be thought of as traveling in the form of waves. Each color has a different wavelength.

Place a jump rope on a table. Have the children move it back and forth "snake" fashion to cause waves in it, then stop it so that it lies on the table in waves. Have the children measure the distance from the top of one wave to the top of the next. This is one wavelength.

The length of a wave of light is measured in *angstroms.* An angstrom is $\frac{1}{1 \times 10^{10}}$ meter, or one ten-billionth of a meter. Have the children find one meter on the meter stick. Then have them find one-hundredth of a meter (centimeter) and one-thousandth of a meter (a millimeter). Can the children imagine how long one angstrom is? *(One ten-billionth of the meter stick.)*

Red light's wavelength is between 6,500 and 8,000 angstroms; violet's is about half that, or 4,000 angstroms. It is this small difference in wavelengths that our eyes translate into different colors.



Learnings: Light is composed of waves of differing lengths. Each color is a wave of different length. Red light has the longest wavelength. Violet light has the shortest wavelength.

ACTIVITY 34 (x,y,z)

OBSERVING THE SPECTRUM

Purpose: To show how the wavelengths of light can be spread into a spectrum

Concept to be developed: A prism can spread light into a spectrum.

Materials needed:

Various sizes of prisms
Projector or flashlight
Paints and crayons
Wrapping paper
3 pieces of window glass cut accurately into rectangular shapes approximately 4 by 8 inches
Waterproof tape
Aquarium cement
Water
Alcohol
Baking pan or tray
Plaster of Paris
Needle, mirror, or shiny key

INTRODUCTION: Review with the children that light travels in the form of waves and that various colors of light have differing wavelengths. Explain to them that the small difference in wavelengths is also enough to cause the light to bend at slightly different angles when passing through various transparent materials, such as water, lenses, and prisms. The short wavelength is bent more than the longer wavelength. The waves, therefore, are bent (refracted) to different degrees, causing the spread of colors. These are the colors of the visible spectrum.

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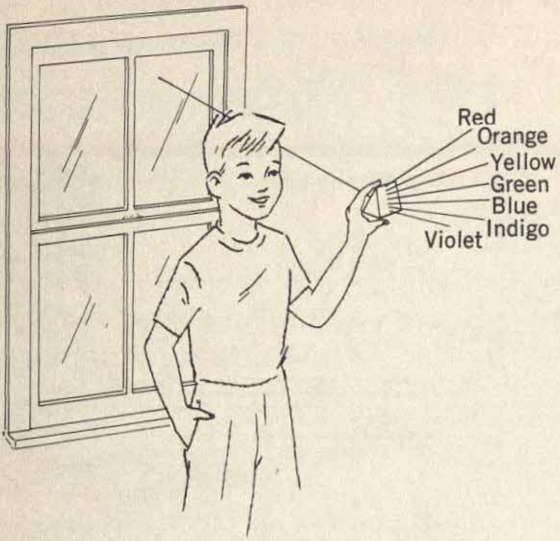
*For a thorough treatment of light waves and wavelengths, see *Energy in Waves,* by Louis Cox (Investigating Science with Children Series; Darien, Conn., Teachers Publishing Corporation, 1964).



Ask a child to stand by a classroom window through which the Sun is shining. Have him hold a prism in the sunlight and turn it until the colors of the spectrum appear on the ceiling or walls of the classroom. Can children describe the colors? Let the children try various sizes of prisms. What effect does prism size have on the size of the spectrum obtained? *(The bigger the prism, the bigger the spectrum.)* Have the children try a light source other than the Sun, such as a projector or flashlight.

Help the children mix paints and find crayons to match the colors of the spectrum. Let them make a large spectrum in the classroom by painting the colors on a long piece of wrapping paper.

Next, suggest that the children build a prism. This may be done by taping together the three rectangular pieces of glass in the shape of a triangle. Set one open end of the triangle into a pan of wet plaster of Paris and allow it to remain in the pan until the plaster has hardened. The prism must be made waterproof, and this can be accomplished by sparingly applying clear aquarium cement. Fill the prism with water. Have the children project a light through the water prism. Allow them to experiment by varying the amount of light passing through the prism.

Next, place black waterproof tape over the lens of a projector, allowing only a thin slit of light to shine onto the prism. Have the children try reflecting the light from a mirror, a needle, or a shiny key. They might also try other liquids in the prism, such as alcohol. The light is refracted at different angles with each. Which produces the best spectrum?

Learning: A prism breaks white light into its component wavelengths.

ACTIVITY 35 (y,z)

MAKING A SPECTROSCOPE

Purpose: To demonstrate how a spectroscope is used

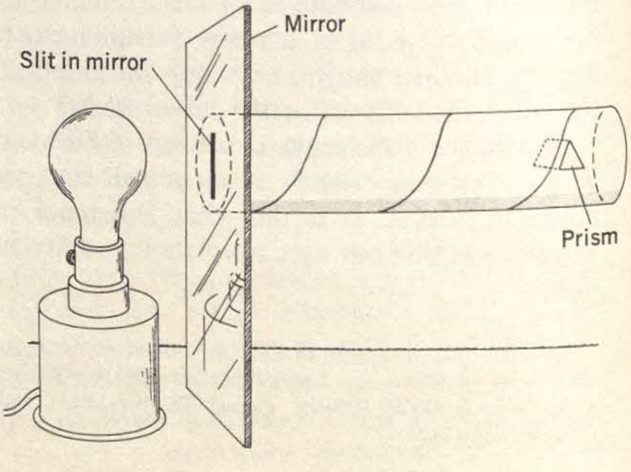
Concept to be developed: Astronomers use a spectroscope to determine the chemical composition of the stars and of the atmospheres of other planets.

Materials needed:

- Small mirror
- Mailing tube
- Adhesive or masking tape
- Light source
- Diffraction grating
- Prism
- Glue
- Aluminum foil
- Razor blade
- Rubber band

INTRODUCTION: Pose this question to the children: Since each element gives off its own peculiar identifying color, how can we tell what the stars are made of? Encourage theories. Explain that the light from a star is gathered in a refracting telescope and caused to pass through a prism in an attachment called a spectroscope. *This is another tool which helps man learn about space. With a spectroscope, the spectrum may be analyzed to see which elements are present. The children may wish to make a spectroscope in the following manner.*

Have the children make a fine scratch ½ inch long on the silvered side of a small mirror. The line should have clean, sharp edges. Have them fasten the mirror to one end of a mailing tube and then cut a hole in the tube so a prism



may be inserted. Let them hold the end of the tube with the slit in front of a light source, look through the open end of the tube, and adjust the prism to give a broad spectrum. (This can be determined only by maneuvering it until the desired clarity is reached.) Then tape the prism in position.

Now suggest to the children that another way to build a spectroscope is with a diffraction grating. A diffraction grating is a transparent piece of glass or plastic on which thousands of parallel lines have been etched. These lines serve to break up the light into a spectrum as does a prism. (Diffraction gratings may be obtained very inexpensively from scientific supply companies.)

Have the children glue a diffraction grating to the end of a mailing tube or other round cardboard tube and then place some aluminum foil over the other end. Make a narrow slit in the aluminum foil with a razor blade. Have a child hold the diffraction-grating end of the tube up to his eye and look through the slit at a light source, rotating the aluminum foil until a spectrum is seen. Fasten the aluminum foil in place with a rubber band.

(Light from an incandescent lamp will give a continuous spectrum, that is, the colors will blend from red to violet without interruption. However, under conditions of low pressure, each element when in its incandescent gaseous state will produce a spectrum with a unique pattern of bright lines. For each element, there will be a bright line spectrum, and each bright line will be in a definite position in the spectrum.

If the light from an incandescent substance under high pressure is permitted to pass through a cooler gas at low pressure, the spectrum will be marked by dark lines. Each dark line will occupy the same position as a bright line in the spectrum as above. Either the dark line spectrum or the bright line spectrum may be used to identify the elements in the gas.)

Extending Ideas: Possibly the school has a spectroscope. If not, try to borrow one from a nearby high school or college. With the spectroscope there are usually tubes of various elements that can be made to glow. Have the children look at the gases through the spectroscope. Help them discover the color and the spectrum produced by various elements. Can the children determine the characteristic patterns of lines produced by each? Ask them to look in books and encyclopedias for pictures of dark line spectra of each element.

Review with the children the fact that from the characteristic patterns of dark lines in the spectrum we can tell what is present in the light source. By comparing *spectrographs* (pictures of the spectrum) produced by certain known elements with a spectrograph of an unknown light source, we can determine what elements are contained in the material emitting the light.

Learning: By taking pictures of the spectrum produced by a star, and comparing them with spectrographs produced by known elements, we can determine what a star is made of.

ACTIVITY 36 (y,z)

OBSERVING THE DOPPLER EFFECT

Purpose: To demonstrate another type of information that can be obtained through the use of the spectroscope

Concept to be developed: The Doppler effect is the name given to the shift of the position of spectral lines when the light source is either receding from or approaching the spectroscope.

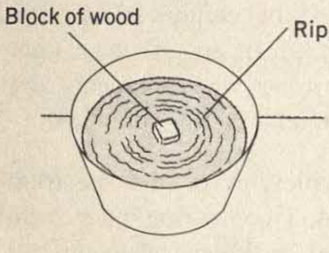
Materials needed:

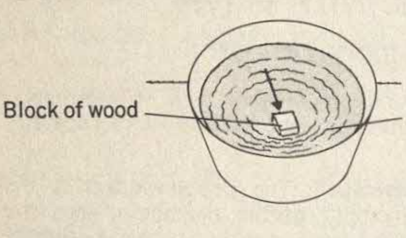
Bicycle
Transistor radio
Block of wood
Pan of water

INTRODUCTION: Point out to the children that when we use the spectroscope we can not only tell what stars are made of, but we also can determine the stars' speed toward or away from us. This is called the Doppler effect. *Explain to them that the Doppler effect is caused by waves of light (or sound, or any other type of wave) that tend to bunch together because of an object's movement in a certain direction. Ask the children if they have ever been at a railroad crossing when a train blew its whistle. Did they notice how the pitch of the whistle seemed to become lower when the train passed? Have they ever driven past an ice cream truck as its song was playing or its bells were ringing? Did they notice a discordant change in pitch?*

The children can experience hearing the Doppler effect by lining up along the edge of a sidewalk. One child, riding a bicycle, should move swiftly past the row of students as he sings, yells, or plays a transistor radio loudly. Have the children listen for the change in pitch as the rider passes.

Another example of the Doppler effect can be seen with ripples in a tub of water. Have a child float a small block of wood in the center of a pan of water. Let another press lightly on the block and watch the pattern of the ripples emanate in rings from the center. Now have the child give the block a slight forward motion. Do the children see how the ripples are closer together in the direction of movement?





As the block moves forward, it compresses the ripples in front of it and expands those behind it.

Now make the point that light energy also comes to us in waves. These waves tend to bunch up in the direction of movement, just as the ripples do. Explain that, by comparing the bands in a light spectrum of a star with a known spectrum, we can see a slight shift in the bands to one side or another. This shift indicates that the light is moving toward or away from the slit in the spectroscope. Light from a source moving toward us will cause a slight shift to the shorter violet end of the spectrum, while light from a source moving away will cause a shift toward the red end.

Learnings: The Doppler effect is the shift of waves so that they are either closer together or farther apart, depending upon the relative movement of the source and the receiver of the waves. Astronomers use the shift in the spectrum to determine whether a light source is moving toward or away from the Earth.

ACTIVITY 37 (y,z)

USING A PHOTOELECTRIC CELL*

Purpose: To investigate the photoelectric cell

Concept to be developed: The photoelectric cell is used to measure small differences in the amount of light reaching Earth from different light sources.

Materials needed:

Photographer's light meter
Various light sources (candle, light bulbs, flashlights)

INTRODUCTION: The camera and the spectroscope do some things that the telescope cannot do to help man gather information about space. Point out that the camera and spectroscope also have their limitations, and that another tool that measures light even more closely and subtly than they do is the photoelectric cell. *The following Activity will show the photoelectric cell at work.*

Help the children learn how to read a light meter (which is an easily obtainable photoelectric cell). Then have them take readings on various light sources, such as a candle, a 40-watt lamp, a 75-watt lamp, the Sun, a flashlight with two new batteries, and a flashlight with more than two new batteries. One group of children may keep records of the readings of the light sources at varying distances. How do they differ when the light is far away and close up? *(The reading is higher when the light is closer.)* Could the stars be classified according to their brightness by this type of method? *(Yes.)* Ask the children how they think astronomers make use of photoelectric cells. *(By comparing the light that reaches the photoelectric cell, they can make fine distinctions about the relative brightness of stars.)*

Learnings: Photoelectric cells can measure small differences in the amount of light reaching them. Astronomers use the photoelectric cell to compare the brightness of stars.

Summing Up Ideas: In this section, the children were introduced to three of the tools the astronomer uses to supplement the telescope in his exploration of space: the camera, the spectroscope, and the photoelectric cell. The camera

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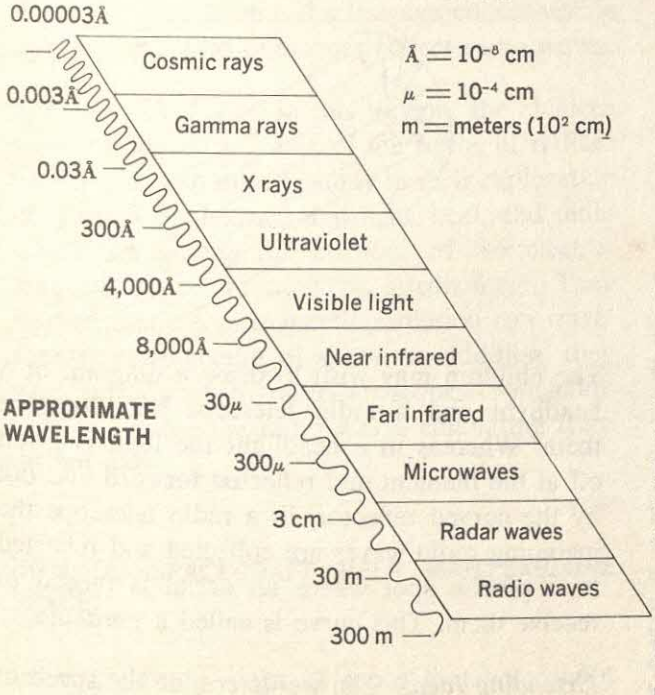
*For an explanation of how a photoelectric cell functions, see *Energy in Waves,* by Louis Cox (Investigating Science with Children Series; Darien, Conn., Teachers Publishing Corporation, 1964).

is used to make a permanent record of observations and to compare the brightness of stars. The spectroscope breaks light down into its component wavelengths. This allows the astronomer to determine the composition of stars and of the other planets' atmospheres, since each element gives off a characteristic spectrum when in the gaseous state. The photocell is used to detect small differences in the brightness of various stars.

HOW CAN INFORMATION FROM SPACE BE INTERPRETED?

Besides light energy, what other forms of energy come to us? How can man use these other forms of energy to explore space? In the vacuum of space, there are many types of energy radiating from the Sun, the stars, and the planets. Generally, all this energy is called "electromagnetic radiation." It includes light energy; but an examination of light energy revealed that it comes to the Earth in waves 4,000 to 8,000 angstroms in length. What about the waves of energy that are less than 4,000 or more than 8,000 angstroms long? Remind the children that an angstrom is one ten-billionth of a meter. What kind of energy would have a wavelength of 1 angstrom? What kind of energy would have waves 1 meter in length? Actually, the only difference between one form of electromagnetic radiation and another is the difference in wavelength.

THE ELECTROMAGNETIC SPECTRUM



We call the electromagnetic radiation that comes to us from space "radiant energy." In addition to visible light, other forms of radiant energy that the astronomer is interested in are heat, X rays, infrared light, ultraviolet light, and radio waves.

ACTIVITY 38 (x,y)

DISCOVERING LIGHT AS RADIANT ENERGY

Purpose: To show that visible light is a form of radiant energy

Concept to be developed: Light waves need no carrier; they travel across a vacuum.

Materials needed:

Clear electric lamp bulb

INTRODUCTION: Now that the children have discovered some of the many forms of radiant energy, they should have an opportunity to look more closely at only one form, light. The following Activity will show them some interesting characteristics of this form of energy.

Have the children examine a clear glass electric light bulb that is lighted. Point out that this is similar to a star burning in space. What forms of energy does the electric light give off? *(Light and heat.)* Can the children see the light it produces? *(Yes.)* Have a child place his hand close to the bulb. Does he feel another form of energy? *(Yes.)* What is it? *(Heat energy.)* What is inside an electric light bulb? *(A filament, which is in a vacuum.)* Why is it in a vacuum? *(If the bulb is to burn for prolonged periods, the filament must be in a vacuum so that no oxygen from the air can oxidize it.)* What carries the heat and light from the filament through the vacuum and the glass? *(Nothing. Radiant energy needs no carrier.)*

Learnings: Light needs no carrier. It travels in a vacuum. It is detected only when something is placed in its path to absorb and/or reflect the radiant energy. In this case, the child's hand absorbs some of the radiant energy.

ACTIVITY 39 (x,y)

DISCOVERING HEAT AS RADIANT ENERGY

Purpose: To demonstrate that heat energy is another of the forms of radiant energy

Concept to be developed: Heat energy can travel through a vacuum, such as space.

Materials needed:

- Electric iron
- World globe
- Thermometer
- Chart paper

INTRODUCTION: Allow a hot iron to represent the Sun and a world globe the Earth. Place the iron close to the globe. After a while have the children feel the globe next to the iron. Be careful not to scorch the globe or burn your hands. Does the globe feel hot?

Now, have the children place a thermometer in the direct sunlight and take a reading. Then place the thermometer in a shady spot and again take a reading. Ask them to keep a record of the readings and compare them. What does the thermometer record in each place? *(The amount of heat energy.)* What energy comes to the Earth from space? *(Radiant heat energy, among others.)*

Learning: Heat energy can travel through space.

ACTIVITY 40 (z)

LEARNING ABOUT RADIO TELESCOPES

Purpose: To demonstrate how to detect radio waves, another of the forms of electromagnetic radiation that come to us from space

Concept to be developed: Just as waves of visible light can be collected by an optical telescope, radio waves can be collected with a radio telescope.

Materials needed:

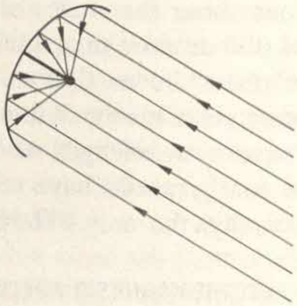
- Flashlight or projector lamp
- Automobile headlight, or reflector for camera flashbulbs

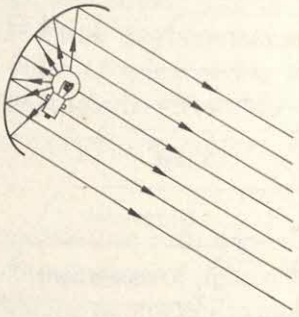
INTRODUCTION: Tell the children the story of Karl Jansky, an engineer who was trying to learn more about the cause of static in radio broadcasts. In 1931 he constructed a large radio antenna of many wires. Jansky was surprised to discover that certain static noises always came from certain locations in the sky and that the movement of the static was in keeping with the movement of the stars. Ask the children to guess what form of radiant energy Jansky discovered coming from space. It was found that radio waves were coming from points in space where no visible light was detected. These locations are sometimes called radio stars. How can radio waves help "map" the universe? Explain that, using radio waves, astronomers have been better able to understand the nature of the center, shape, and structure of our galaxy—the Milky Way—and other galaxies. Many questions have also been raised regarding the nature of radio waves from clouds of hydrogen gas and the planets Jupiter, Saturn, Venus, and Mars.

Have the children examine a flashlight, an automobile headlight, a carbon arc searchlight, or other *parabolic*-type reflectors. Ask them to locate the light source and the reflective surface of each. Discuss with the children the shape of the reflective surface. Have them collect examples of parabolas, including mirrors, bowls, lenses, solar furnaces, antennas, etc.

Shine a flashlight or projector lamp into the various reflectors the children have collected. Can they determine the point at which the light rays focus?

The children should discover that actually the direction in which light travels from a headlight or searchlight is exactly opposite to that traveled by the radio waves to a radio telescope.





The children may wish to draw a diagram of a headlight and a radio telescope and compare them. Whereas in a headlight the light is given off at the filament and reflected forward and out by the curved reflector, in a radio telescope the incoming radio waves are collected and reflected to a precise spot where an aerial is placed to receive them. This curve is called a *parabola.*

Extending Ideas: Can we determine the speed of radio stars? *(Yes, by using the Doppler effect,* *as with light and sound.)* Can the children suggest reasons why radio telescopes can be used when optical telescopes cannot? *(Light waves, utilized by optical telescopes, are disturbed by the atmosphere. Radio waves, however, are not as affected. Radio telescopes can be used during the daylight hours, but optical telescopes cannot. The best locations for optical telescopes are high in the mountains, away from city lights, haze, and smoke. Radio telescopes are affected by other radios, heat, airplanes, and machines generating an electromagnetic field.)*

Have the children collect pictures and information about the world's great radio telescopes. Let them discuss the relative sizes and shapes of radio telescopes in Jodrell Bank, England; Cambridge, England; Malvern, Australia; Leyden, Holland; Green Bank, West Virginia; and others. What is noticed about the sizes of them? Which is the largest? Are all radio telescopes constructed in the shape of parabolic dishes? Why are other shapes used?

How are radio telescopes similar to optical telescopes? How are they different? *(Just as an optical telescope mirror brings the light waves together at a point to be magnified by the eyepiece magnifier, so a radio telescope brings the radio waves together at a point to be amplified by a radio amplifier.)*

Learning: Just as optical telescopes collect visible light waves, radio telescopes collect radio waves.

Summing Up Ideas: In this section, the children were introduced to some of the forms of radiant energy that astronomers study in their exploration of space. They learned that light, heat, and radio waves are among the portions of the electromagnetic spectrum used by astronomers. They learned that electromagnetic radiation can travel through the vacuum of space. In addition, they were introduced to radio telescopes, which are used to receive the radio waves emanating from distant stars.

HOW DO SPACECRAFT HELP MAN EXPLORE SPACE?

What conditions exist in space that we cannot determine from our Earth-bound home? Even with the most powerful telescopes, spectroscopes, and cameras, it is not yet possible to gather information regarding the possibility of other life in space; conditions on the Moon and other planets; the cause, extent, and effects of solar radiation; the nature of other stars; and the extent of the universe. How, then, can we determine these conditions in space?

In order to do this, many satellites and space probes have been and are being designed to gather this information. These spacecraft and the equipment aboard them are special tools of research designed to gather scientific data just as a telescope, camera, or spectroscope is used to gather data. This section deals with the variety of tools that are sent into space and the questions about which they are gathering data.

ACTIVITY 41 (x,y,z)

KEEPING A SPACE EXPLORATION LOG

Purpose: To record the types and missions of some satellites and space probes

Concept to be developed: Man uses spacecraft of various types to help him explore space.

Materials needed:

Large sheet of chart paper

INTRODUCTION: To familiarize the children with the terminology of space exploration, discuss the words space probe, orbit, *and* satellite *with them. Space probes are sent into space to collect information. Some space probes go into space and then return to the Earth. Others are sent into orbit around the Earth. These are called satellites. Others are sent to the Moon or to the other planets to gather information there. Still others are sent deep into space or around the Sun.*

Help the class keep a space exploration log. Have them make a record of various scientific satellites and space probes, noting the date of the launching, the name of the space probe, its scientific mission, the type of rocket booster used, any peculiarities of orbit or trajectory, and any other data necessary to keep the log accurate and current. Sources of information are the radio, television, newspapers, and periodicals. Possibly a space scientist in the community ca help contribute additional data.

Learning: Man uses a wide variety of spac craft to help him explore space.

TYPICAL SPACE EXPLORATION LOG

Name of space probe	Date of launch	Scientific mission	Trajectory or orbit	Launch booster	Description	Remarks
Explorer VII	Oct. 13, 1959	1. To measure radiation from the Sun 2. To measure radiation from the Earth's atmosphere 3. To measure radiation absorbed by the Earth's atmosphere	Perigee—344 mi. Apogee—678 mi.	Juno II	Weighs 91.5 lbs. Shaped like 2 cones	Expected to orbit 20 years.
Ranger II	Nov. 18, 1961	Attempt to orbit the Moon	Perigee—98 mi. Apogee—147 mi.	Atlas–Agena B	Weighs 675 lbs.	Attempt to reach the Moon failed; satellite orbited the Earth for 2 days.
Mariner II	Aug. 27, 1962	1. To collect information regarding the atmosphere of Venus, including signs of water vapor, oxygen, etc. 2. To determine the surface temperatures of Venus 3. To gather information on magnetic fields, radiation, and cosmic dust	To intercept the planet Venus, pass about 10,000 mi. from Venus, go into orbit around the Sun	Atlas–Agena B	Weighs 446 lbs. 9,800 solar cells on 2 panels	Passed 21,000 mi. from Venus. Transmitted data from about 36,000,000 mi. in space.
Alouette	Sept. 29, 1962	To chart the ionosphere	Perigee—619 mi. Apogee—640 mi.	Thor–Agena B	Weighs 320 lbs.	First international satellite

ACTIVITY 42 (x,y,z)

SHOWING A MAGNETIC FIELD*

Purpose: To demonstrate the existence of magnetic fields

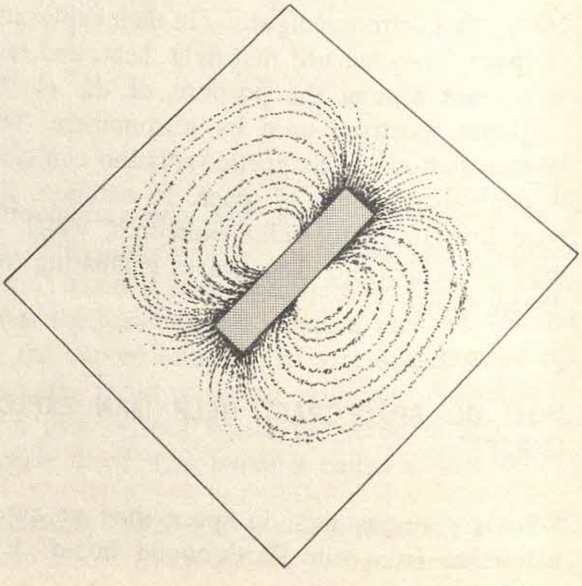
Concept to be developed: Magnets are surrounded by magnetic fields.

Materials needed:

- Bar magnet
- U-shaped magnet
- Horseshoe magnet
- Masking tape
- Iron filings
- Pane of window glass, about 1 foot square
- Nails and tacks
- Ruler

INTRODUCTION: Present to the children the idea that the Earth is a giant magnet that attracts other things. To see why this is so, the children must understand the principle of a magnetic field, which is what surrounds the Earth. This can be simply done by using various kinds of magnets, as in the Activity that follows.

To help the children discover the magnetic field around each magnet, have them tape a bar magnet to the bottom side of a piece of glass and sprinkle iron filings on top of the glass. Then let them tap the glass gently until the iron filings form a pattern over the area of the magnet. Have



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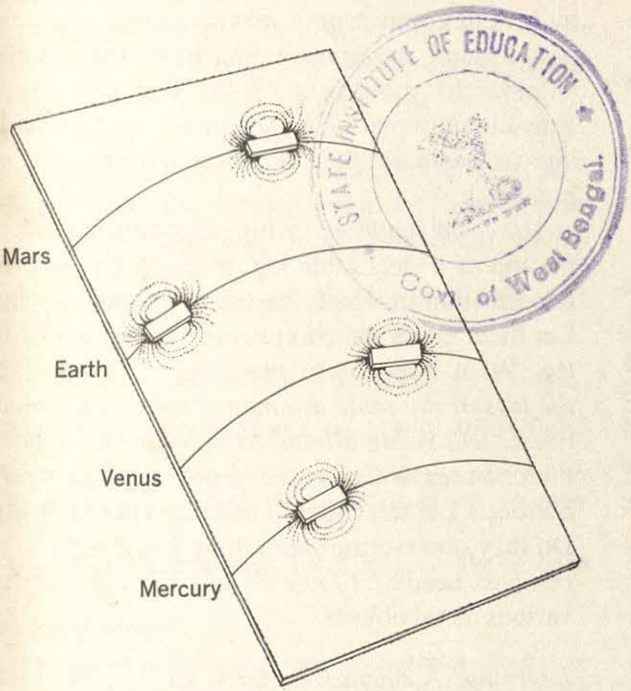
*To develop further the concept of magnetic fields through other Activities, see *Energy in Waves*, by Louis Cox (Investigating Science with Children Series; Darien, Conn., Teachers Publishing Corporation, 1964).

the children try other magnets of different shapes. How do their magnetic fields differ? *(The magnetic field of each extends from pole to pole.)*

Tape several small magnets to the underside of the piece of glass. Tell the children that these magnets represent four planets—Mercury, Venus, the Earth, and Mars. Sprinkle iron filings on the glass and let the children tap it until patterns have formed around each magnet. Since the Sun sends out electrons in all directions in space, the children can hypothesize as to whether the other planets might have magnetic belts similar to Earth's. How could we find out? *(By space probes.)* How could we find out if other planets are magnets like the Earth? How could we find out if they have a magnetic field surrounding them? Help the children look in books and encyclopedias to find out if other planets have magnetic fields. What have space probes told us about magnetic fields of other planets? How did we find out about Venus? *(The space probe Mariner II sent back information.)*



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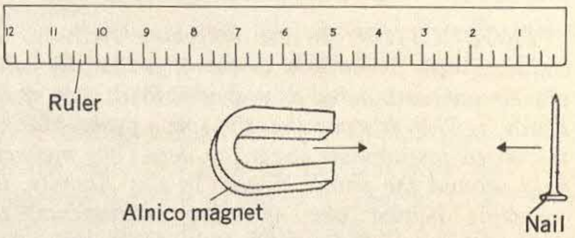
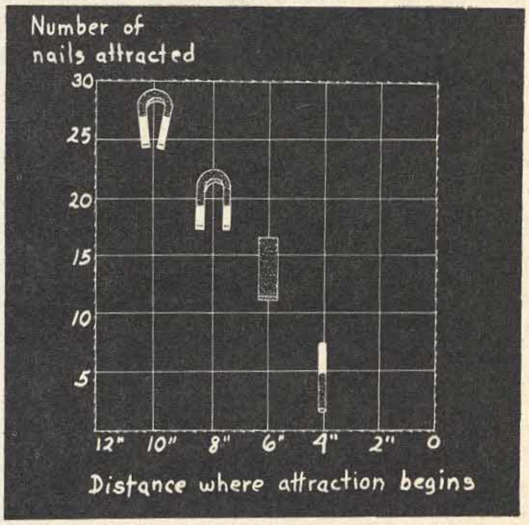
Extending Ideas: Some children may be interested in the strength of magnetic fields. Let the children see how many iron nails or tacks each magnet will pick up. Some may be "8-tack" magnets, while others may be "50-tack" magnets.

One group might measure the distance at which each magnet will begin to make the nails roll toward the magnet. Have them place a ruler on the table with a nail placed at the 1-inch end. Let them slide the magnet along the edge of the ruler from the 12-inch end to the 1-inch end. When the nail begins to roll toward the magnet, ask them to stop the magnet and record its distance from the 1-inch end. Keep a record of the distance at which each magnet begins to attract the nail.





Have the children make a graph showing the relation between the number of nails each magnet picked up and the distance at which it attracted a nail. Have the children repeat the tests several times for greater accuracy.

Be sure that the children discover that we cannot now detect and measure the magnetic fields of other planets by using instruments on the Earth. Space probes must be sent to or close by the planets with instruments aboard to gather this data. Explain to the children that some space probes have instruments to measure the magnetic fields of other planets. One is called a magnetometer.

Learnings: Magnets are surrounded by magnetic fields. Planets are also surrounded by magnetic fields.

ACTIVITY 43 (x,y,z)

MAKING A MAGNETOMETER

Purpose: To illustrate the type of equipment carried by space probes

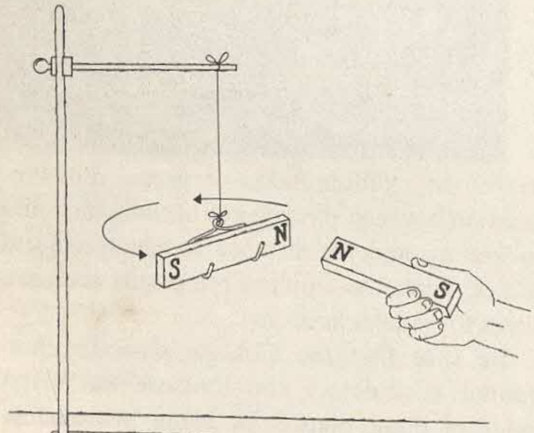
Concept to be developed: Some space probes carry instruments, such as the magnetometer, to detect the magnetic fields around other planets.

Materials needed:

2 bar magnets
String
Compass

INTRODUCTION: In the preceding Activity, the children were introduced to the idea that the other planets are surrounded by magnetic fields, just as the Earth is. They learned that the space probe Mariner II carried instruments aboard to detect the magnetic field around the planet Venus. In this Activity, the principle behind one of these instruments, the magnetometer, *will be demonstrated for them.*

The children can make a magnetic field detector simply by constructing a free-moving magnet. (This, incidentally, is also the principle of the compass.) There are many ways to do this. One way is to suspend a bar magnet by a string and allow it to rotate freely. When it stops, have the children note the direction in which it points, then tap it gently to cause it to swing again. When it stops, ask them to note the direction in which it is aligned. Is it the same as before? *(Yes.)* Why? *(The magnet has aligned itself with the Earth's magnetic field.)* Have the children bring a second magnet close to the first magnet. What happens? *(The first magnet moves.)* Why? *(The magnetic fields of the two magnets interact.)* Ask the children, "Do you think the same thing would happen if the magnetometer were placed near Mars? Venus? Near the Moon?"



Some children might try to detect magnetic fields of objects on Earth. Sometimes a piece of steel or iron equipment that has been left undisturbed for a long period of time will become magnetic. The metal legs of a table or chair may become magnetized. Establish that a compass will move when brought near a magnetic field by bringing one near a magnet. Move the compass around the magnet and have the children observe the movement of the compass needle. Why does it move? *(The needle is a small magnet, and its magnetic field interacts with that of the magnet.)*

Have the children bring a compass close to the top of a steel table leg or steel cabinet. Note the direction in which the compass needle points. Let them move the compass to the bottom of the leg. What happens to the compass needle? *(If the legs of the table are magnetized, the compass needle will swing around to point in the opposite direction as it is moved from the top to the bottom.)* Let the children test the other table legs. Do they observe the same thing happening to the compass needle? *(They should.)* Have them test various metal objects.

Learning: A magnetometer is used to detect the magnetic fields around the other planets in the solar system.

ACTIVITY 44 (z)

MEASURING RADIATION IN SPACE

Purpose: To introduce the idea that instruments are placed in probes to measure the amount of radiation in space

Concept to be developed: Some radiation can be measured with a Geiger counter.

Materials needed:

Geiger counter
Radioactive materials, such as a radium-painted watch dial or radioactive minerals

INTRODUCTION: Ask the children, "How can man measure radiation in space?" Remind them that we know radiation is always coming from the Sun, that some radiation we can see, and that other forms of it we can detect. But how can we tell how much *radiation there is coming from the Sun or surrounding distant planets? The following Activity will show* *one of the ways in which the amount of radiation can be measured.*

The school may have a Geiger counter. If not, one can be obtained from a scientific or mineral supply house. Possibly someone in the neighborhood, high school, or college will demonstrate one to the class. Help the children learn how to use the Geiger counter. They can measure the radiation by counting the "clicks" it makes when exposed to the air, a radium watch dial, or other radioactive materials.

Ask the children to observe the size of the Geiger counter. Would it fit aboard a statellite sent into space? *(No.)* Encourage the children to speculate as to the suitable size for a Geiger counter to be placed in a spacecraft. Discuss with children how the "clicks" could be "heard" from space. *(The information is radioed to Earth.)*

Learning: Radiation in space can be measured.

ACTIVITY 45 (y,z)

DETECTING THE PRESENCE OF LIVING ORGANISMS

Purpose: To explore the ways in which space probes can be used to detect the presence of life on other planets

Concept to be developed: There may be life on other planets.

Materials needed:

Pyrex Petri dishes, plastic refrigerator boxes, or other clear containers that can be sterilized and sealed
Large pot and water for sterilization
Agar or gelatin
String

INTRODUCTION: Ask the children, "How can we tell if there is life on other planets?" Tell them that scientists are now trying to determine if there could be some forms of living organisms on other planets. In order to detect life, they must speculate as to what that life needs in order to live and grow. If the scientists use the correct environment for growth, they may be able to detect extraterrestrial life. Point out that some space probes carry instruments that may determine the existence of life beyond the Earth. One possible way to do this is called the Gulliver, *or "sticky string." After the spacecraft lands on a planet, the "sticky string" or tape will be unrolled over the planet's surface.*

Explain to the children that the idea is that the "sticky string" will pick up whatever is on the surface of the planet and bring it back to the instrument. Inside the instrument, there will be nutrients necessary for the growth of living organisms. If there is life on other planets, and if they can utilize the nutrients in the instrument, and if such life can be detected, this information can be radioed back to Earth. To simulate what might happen in such an experiment, the following Activity may be performed.

Have the children sterilize several of the containers by boiling or steaming them (as is done with nursing bottles) for about 20 minutes. Into each container, let a child pour enough agar or liquid gelatin to cover the bottom to ⅛ inch. Cover the containers and allow them to cool. Have another child take several 8-inch pieces of damp string that also have been sterilized and drag them over the lawn, across the soil, or over the classroom floor. Ask the child to place them in the dishes of agar or gelatin. Save one container of nutrient to use as a control. Cover each dish and allow them to remain in a warm place for several days. Do not open them, but have three children observe each dish every day, keeping a record of their observations. Do they notice any life appearing on or around the string on the gelatin? *(Bacteria, molds, or yeasts may begin to grow on the nutrient.)* Do any forms of life grow on the control nutrient? *(No.)* Would this experiment prove that all living things that are on the nutrient have been detected? *(No. There may be organisms that live on other nutrients and organisms that live at other temperatures.)*

Develop with the class such questions as: What do living things need to grow? What do they take from their environment to grow? What do they give back to the environment? What do animals need for growth? What do plants need?* (Develop the concept of the exchange of carbon dioxide and oxygen between plants and animals in the processes of respiration and photosynthesis.)

Learnings: Life may exist on other planets. Space probes can carry instruments to detect this life if it exists.

Summing Up Ideas: In this section, the children learned about some of the ways man uses space-

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*For a further discussion of materials needed for growth, see *Living Things,* by James Wailes (Investigating Science with Children Series; Darien, Conn., Teachers Publishing Corporation, 1964).

craft to explore space. They learned of the different types of satellites and space probes and of some of the equipment these carry. They learned that the Earth and the other planets are like giant magnets, and that they each have magnetic fields, of varying strengths, around them. In addition, the children learned some of the ways that man can find things out about other planets: by testing the space around them with magnetometers, their atmospheres with limewater, and their soil with "sticky strings" and nutrient cultures.

WHAT CAN WE FIND OUT ABOUT THE MOON?

The Moon is our nearest neighbor in space. It will be the first celestial body man lands on as he explores space. Therefore, man has already learned a great deal about the Moon in preparation for the first trip to it; Moon probes have been launched in an effort to find out still more.

ACTIVITY 46 (x,y,z)

FINDING OUT ABOUT THE MOON

Purpose: To establish those facts that are already known about the Moon

Concept to be developed: We already know a great deal about the Moon.

Materials needed:

None

INTRODUCTION: Ask the children what they would like to know about the Moon. What do they already know about the environment of the Moon? How do they know? How can they find answers to what they don't know? Do scientists have some good hypotheses about the Moon? What knowledge and tools can we work with? What tools could we design to send to the Moon to gather data? What must be known about the Moon before man can go there himself?

Make a list of the children's questions about the Moon. Have them do research to find not only the answers but also *how* we know what we know. Help them look in books and other reference sources, seek answers from others who know, watch motion pictures and television, write to sources, and conduct experiments and demonstrations. Have them make a chart, such as the following, to show questions that can be answered through reading, experimenting, measuring, etc. Which questions have no answers as yet? For which questions must more data be gathered?

Learning: Many facts are already known about the Moon, but many others remain to be discovered.

QUESTIONS AND ANSWERS ABOUT THE MOON

Questions about the Moon	Some possible answers (Hypotheses)	How does man know? Some ways to find out, using tools, experiments, knowledge, resources, etc.
How far is it to the Moon?	About 240,000 miles	Radar; sending light signals to the Moon and recording time for the light to make a round trip.
What is the diameter of the Moon?	About 2,106 miles	Use triangulation. Hold a coin between the eye and the Moon. Find how far away it must be held to eclipse the Moon completely. Measure the diameter of the coin and the distance from the eye. Can these proportions help determine the Moon's diameter?
Does the Moon have a magnetic field?	?	Magnetometer must be sent aboard spacecraft to vicinity of the Moon.
Does the Moon have gravity?	Yes	1/6 that of the Earth. All bodies have a gravitational pull at the surface, according to their mass and size. (Mass of Moon is about 1/80 mass of the Earth.)
Is there life on the Moon?	?	?
Is there atmosphere on the Moon?	?	?
Is there water?	?	?
What is the Moon made of?	?	?

ACTIVITY 47 (y,z)

STUDYING THE MOON'S CRATERS

Purpose: To hypothesize about the Moon's craters

Concept to be developed: The Moon's surface contains craters of unknown origin.

Materials needed:

Ruler
Compass for drawing circles
Pictures of craters on the Moon and the Earth

INTRODUCTION: Their discussion in Activity 46 will have shown the children that there are still many unanswered questions about the Moon. Go on to discuss the surface of the Moon with them. Explain that some scientists think the Moon's craters were caused by volcanoes. Others think they were caused by meteors striking the Moon's surface. In order to find answers to these questions, scientists send instruments to the Moon to gather information. Pictures of the Moon's craters are compared with pictures of volcanoes and meteor craters on the Earth. Conditions on the Moon are simulated on Earth and bombarded with meteor-like objects. Television cameras, drills, and probes mounted on spacecraft send information to us about the Moon. The following Activity may help clarify the children's thinking and point up the lack of definite answers about the Moon.

Have the children collect pictures of various volcanoes on the earth: Suggest Paricutín, Vesuvius, and Mauna Loa to start with. Ask them to collect pictures of places on Earth where there has been considerable volcanic activity, such as Hawaii, Craters of the Moon National Park, and the Azores. Have them compare these pictures with pictures of the Moon's surface. Do the children notice any similarities or differences? Ask if they think the Moon's craters were caused by volcanoes. Have the children collect pictures of craters that were caused by giant meteors impacting the Earth, such as those in Arizona and South Africa. Ask them to compare these with the picture of the Moon's surface. Do the children think meteors caused the Moon's craters?

Help the children draw circles to scale, showing the size of the Moon's craters. Using the same scale, have them draw circles showing the size of several of the Earth's volcanoes. How do they compare in size? *(The Moon's craters are larger.)* What is the size of some of the meteor craters on the Earth? *(Very large.)* Suggest that children draw them, using the same scale, and compare them with the Moon's craters.

Learnings: The Moon's surface is covered with craters. The origin of the craters is unknown.

ACTIVITY 48 (x,y,z)

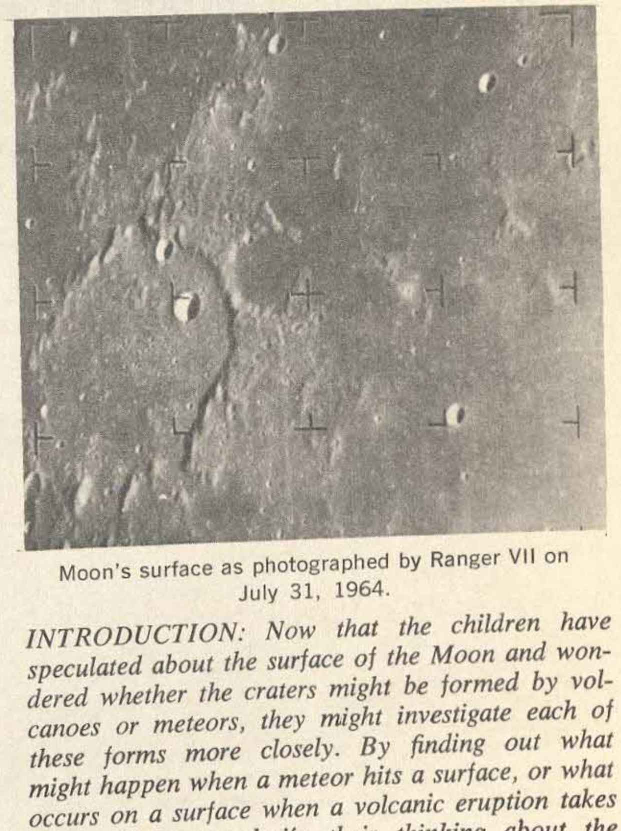
SIMULATING THE MOON'S SURFACE

Purpose: To establish that little is known about the surface of the Moon

Concept to be developed: The Moon's surface may be composed of dust, or it may be composed of solid rock.

Materials needed:

White tempera powder or plaster of Paris
Water
Marbles
Aluminum pie plate or wide tin can
Electric hot plate
Several boxes
Rocks
Beach sand
Peat moss
Feathers
Lint from a clothes dryer
Steel or iron filings



Moon's surface as photographed by Ranger VII on July 31, 1964.

INTRODUCTION: Now that the children have speculated about the surface of the Moon and wondered whether the craters might be formed by volcanoes or meteors, they might investigate each of these forms more closely. By finding out what might happen when a meteor hits a surface, or what occurs on a surface when a volcanic eruption takes place, they may clarify their thinking about the possible formation of the craters of the Moon.

Into a pile of dry tempera powder or plaster of Paris, have a child drop several marbles that represent meteors. Have the children notice the type of crater that results. Does this resemble the Moon's surface?

Next, have a child boil a small amount of water in a small aluminum pie plate or wide tin can. Use an electric hot plate as a source of heat. When the water reaches boiling, have the child sprinkle in enough plaster of Paris to make a thick and creamy mixture. Then turn the heat down so that the mixture continues to bubble slowly. When the mixture hardens, remove the pan from the hot plate. Let the children examine the surface of the mixture. Does it resemble volcanoes? Ask the children if they think it resembles the Moon's surface. Why?

Ask the children to explain what the difference is between these classroom activities and what may be taking place on the Moon. Introduce the terms *temperature, pressure, gravity,* and *erosion,* and have the children look them up in the dictionary to make sure of their meaning. Encourage the children to discuss generally what they know about the effects these factors have on the Earth's surface. Are these same conditions present on the Moon's surface? Can the children think of some ways to find out?

Introduce another question: Is the Moon's surface hard and rocky or soft and dusty? How can we find out? Can the children design some equipment to place aboard the spacecraft to find out?

Have the children fill each box with the various materials to a depth of several inches. Let them feel each material and press their fingers down on it. Will the surface of the Moon be like the feathers or the rocks? The sand or the lint? Encourage the children to speculate as to the design of a tool to find out. Perhaps some children may wish to design such a tool.

Have the class examine a drill bit and samples of various cores of earth obtained when drilling test sites, water wells, or oil wells, if these are available. Could a lunar drill be placed upon a spacecraft to examine the lunar surface at varying depths?

A third point may be raised: How could we find out the chemical composition of the moon? (Help the children recall how they identified spectroscopic colors of heated elements.) Could materials on the moon be identified by using a spectroscope? Ask the children, "What else could be placed aboard the lunar spacecraft?" *(Television cameras, explosives, seismometers, flares, living things, telescopes.)* What would each one help us know about the Moon?

Learnings: Very little is presently known about the Moon's surface. It may be soft and powdery, or it may be hard and rocky.

Summing Up Ideas: In this section, the children were introduced to the little that is known about our nearest neighbor in space, the Moon. They learned that craters cover the Moon's surface and some of the theories of their origin. They also learned that little is known about the Moon's surface; it may be soft and powdery or hard and rocky.

IMPORTANT IDEAS IN THIS CHAPTER

For the kindergarten, primary, and intermediate grade children, the ideas with the most meaning and application are:

- Some of the light from the Sun and the other stars comes directly to our eyes; some of their light is reflected to us by other heavenly bodies.
- We do not see the stars during the daylight hours because their light is obscured by the Sun's light.
- Telescopic devices make objects seem larger and closer.
- Curved objects tend to act as magnifiers.
- When a camera is pointed toward the night sky and a time exposure is taken, the stars appear as arcs of light; these are called "star trails."
- A photograph provides a permanent record of observations.
- Light is composed of waves of differing lengths; each color of the spectrum is a wave of different length.
- A prism breaks white light into its component wavelengths.
- A spectroscope is used to determine the chemical composition of the stars.
- Electromagnetic radiation, such as light and heat, can travel through a vacuum.
- Man uses a wide variety of spacecraft to help him explore space.
- Magnets are surrounded by magnetic fields; planets are also surrounded by magnetic fields.
- Many things about the Moon have yet to be learned.

In the intermediate and upper grades, the children should be led to develop concepts that are more complex and quantitative:

- The power, or magnification, of a lens is the number of times it increases the size of an object.
- The focal length of a lens is the distance from the center of the lens to the point where the rays of light passing through the lens cross.
- In a refracting telescope, one lens (of long focal length) forms an image at a point in front of our eyes where we can look at it through another lens (of short focal length).
- The magnification of a refracting telescope is found by dividing the focal length of the objective lens by the focal length of the eyepiece lens.
- A spectroscope can be used to see if stars are moving toward or away from the Earth.
- Photoelectric cells can measure small differences in the amount of light reaching them.
- Radio waves from space are collected by radio telescopes, just as waves of visible light are collected by optical telescopes.
- A magnetometer is used to detect magnetic fields around the other planets in the solar system.
- A Geiger counter can be used to measure the amount of radiation in space.

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4

INVESTIGATING HOW MAN GETS INTO SPACE

As one might expect, now that we are in the age of space exploration, children's questions are inspired by some of the things they read and hear, questions like:

"What is meant by 'escape velocity'?"

"How does a rocket work?"

"What is an orbit?"

"How are rockets guided?"

"What do rockets use for 'gasoline'?"

Achieving the impossible seems always to be the goal of man. A few years ago, the statement that everything that goes up must come down was thought to be true. At one time in man's history it was also thought that the Earth was square. Later, man came to think of the Earth as being spherical in shape; now the Earth has been found to be slightly pear-shaped. And although man was thought never to be able to exceed the speed of sound, in 1962 he traveled at speeds of over 17,500 miles per hour.

With each step into space, man accepts the challenge of solving the myriad complex problems associated with it. Having always lived under the conditions of Earth, it is difficult for man to imagine what it will be like in a foreign environment. Human bodies are constructed to utilize and interact with the resources of their surroundings. The force of gravity is put to use in moving from place to place, in constructing buildings, and in designing machines. Friction is utilized to do work and to harness energy. The atmosphere enables man to carry on biological functions and to communicate.

As man leaves the comforts of Earth, however, these same factors stand in his way. He must overcome gravity. He must design instruments to withstand the effects of friction. He must overcome or take with him those factors of the atmosphere on which he is dependent.

In this chapter, the following questions will be explored:

How do rockets work?

What powers a rocket?

How is a rocket placed in orbit around the Earth or another planet?

How can a rocket be sent in the designated direction?

What is an orbit?

Some of the concepts and principles that this chapter will deal with are: gravity, Newton's third law (action–reaction), orbits, energy sources, navigation, and guidance.*

WHAT HOLDS US BACK?

Man has always dreamed of leaving the Earth. His attempts have continually been frustrated because of his inability to cope with the Earth's *gravitational attraction* for other objects. Each object in the universe has an attraction for each other object. Its attraction is dependent upon the mass of the two objects and the distance between them. The larger the mass, the greater will be the attraction. The closer together the objects are, the greater will be the attraction. This attraction or pull is called *gravity*.

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*For Activities dealing with gravity and action–reaction in greater detail than those in this book, see *Motion*, by Lois Dunn (Investigating Science with Children Series; Darien, Conn., Teachers Publishing Corporation, 1964).

ACTIVITY 49 (x,y,z)

DISCOVERING GRAVITATIONAL ATTRACTION

Purpose: To demonstrate the gravitational attraction of the Earth

Concept to be developed: The Earth pulls all objects toward its center.

Materials needed:

Bathroom, balance, spring, and laundry scales (Possibly the school nurse can supply some.)
Various objects for measuring
String and weight for a plumb line
Pipe cleaners
World globe
Ball or other unbreakable objects
Modeling clay

INTRODUCTION: How much does the Earth's gravity pull on various objects? Ask the children if they think the Earth pulls on them.

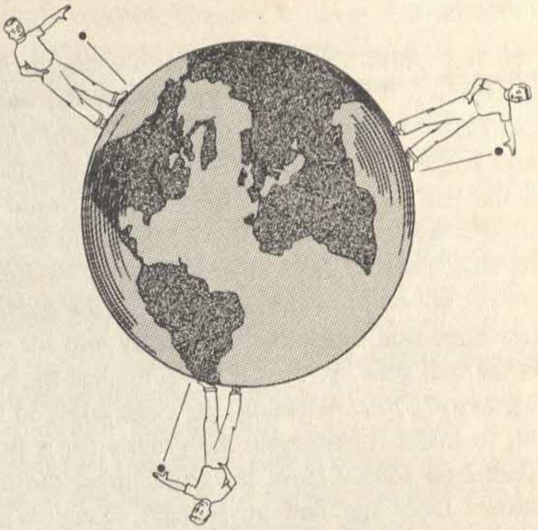
Each child can find out how much gravitational force the Earth is exerting on him by weighing himself and recording his weight. Explain to the class that a person's weight is a measure of the Earth's pull on his body. If a child registers a weight of 100 pounds, the Earth is pulling at him with a force of 100 pounds. Using various scales—balance, spring, and laundry scales—measure various objects to find the amount of gravitational pull on each.

Next, the children can discover that gravity attracts all objects toward the center of the Earth by dropping a ball or other unbreakable object. Have the children observe the direction of fall.

Have them also construct a plumb line by attaching a weight to a string. Suspend the string so that it will swing freely. When it stops swinging, let the children observe it to see if the string is perpendicular to the ground. Ask them in what direction gravity is pulling on the weight. *(Straight down.)* What if the plumb line were on the other side of the Earth? Would it hang in the same direction? *(Yes.)*

Using modeling clay, attach pipe-cleaner figures to a world globe. Help the children determine the direction of the force of gravity if a person (represented by a pipe-cleaner figure) were to drop an object. These activities will help the children to see that the attraction of gravity is generally toward the center of the Earth.

Extending Ideas: Gravitational force is also affected by distance. As an example, small differences in the weight of an object have even been detected between sea level and a mountaintop. Thus, as two objects become farther apart, the gravitational attraction between them becomes less. It decreases inversely as the square of the distance between the object and the center of the Earth. Therefore, at 8,000 miles from the Earth's center a person's weight is only 1/4 of his weight on the Earth's surface. At 12,000 miles it is 1/9. At 16,000 miles it is 1/16. This can be determined with an instrument called a *gravimeter.* Have the children compute their weights at each of these distances.



Learning: The Earth's gravitational attraction pulls objects toward the center of the planet.

ACTIVITY 50 (x,y,z)

OVERCOMING THE PULL OF GRAVITY

Purpose: To show that the Earth's gravitational attraction can be overcome

Concept to be developed: If a great enough force is exerted in a direction opposite to the gravitational force exerted by the Earth, an object can rise.

Materials needed:

Large ball

INTRODUCTION: In order to overcome the Earth's gravitational force, man has had to devise ways of counteracting it. Ask children if they can overcome the pull of the Earth's gravity for a brief period. Have them jump into the air. Ask them if, when they rise into the air, they have overcome the

Earth's attractive force. The following simple activity will help them to discover more about this force and how it works.

Have a child hold a ball at arm's length. Ask the children, "Is the earth pulling on the ball?" *(Yes.)* How much? *(The force is the weight of the ball.)* Is the child overcoming the force of gravity on the ball? *(Yes. Otherwise, the ball would be falling.)* When his arms tire, let the child release the ball. Does it fall? *(Yes.)* Why? *(The Earth attracts the ball toward the center of the planet.)* Now have him throw the ball gently into the air. As the ball goes up, does it travel against the pull of gravity? *(Yes.)* What did the child apply to the ball to make it overcome the gravity for a brief period? *(A force.)* Have the child throw the ball harder. Does the ball go higher? *(Yes.)* Why? *(He has applied a greater force.)* See who in the class can throw the ball the highest. Could anyone throw the ball into space? *(No.)* Why? *(No one can apply a force great enough to overcome the Earth's gravitational force indefinitely.)*

As the children throw the ball into the air, can they determine the point at which the ball begins to fall back to the Earth? *(Yes.)* Why does the ball fall back? *(The ball travels upward because it has initially been given enough upward push by the child to exceed the downward pull of the Earth's gravitational attraction. The gravitational pull, however, eventually overcomes the child's push, and the ball therefore returns to Earth.)*

Extending Ideas: Actually, little is understood about the cause of the Earth's gravitational pull. It is difficult for scientists to give a satisfactory explanation. The nature of gravity is one of the big question marks in the universe. The children should be helped to see that this phenomenon provokes much inquiry and that it is an example of the fact that scientists do not know all the answers.

Some basic understandings that are known about gravity, however, are that any object has an attraction toward any other object; that the attraction is toward the center of that object; and that the attraction decreases with distance, but never disappears completely.

Learning: The pull of gravity can be overcome by exerting a sufficient force in the opposite direction.

ACTIVITY 51 (y,z)

OBTAINING THE ENERGY TO OVERCOME GRAVITY

Purpose: To demonstrate that machines may be used to overcome the attractional force of the Earth

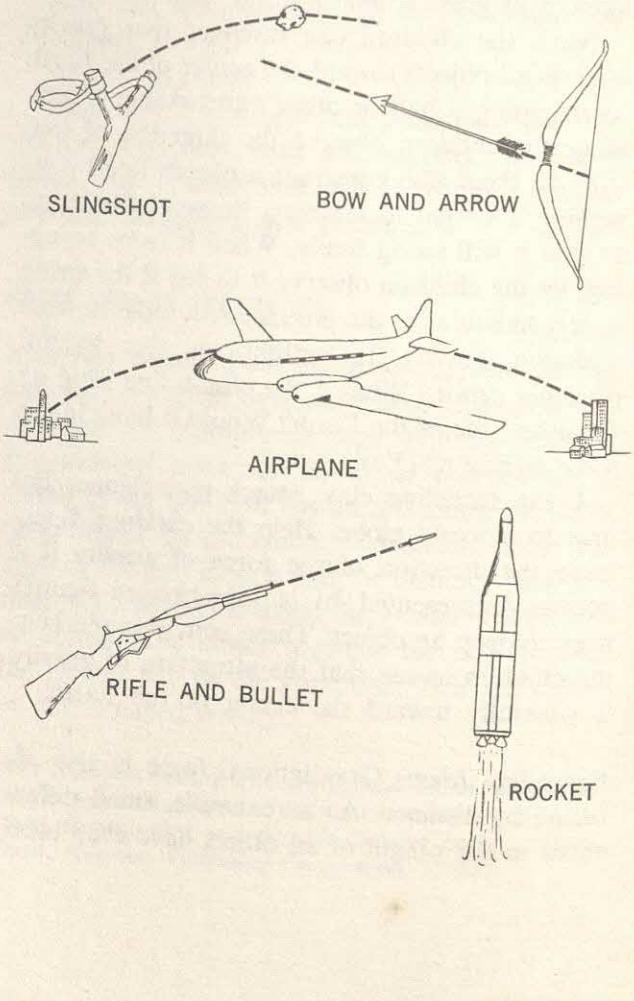
Concept to be developed: To overcome the Earth's gravitational attraction, large amounts of energy must be expended.

Materials needed:

Candle
Jars
Baking soda
Broom straw or wood splint
Hydrogen peroxide

INTRODUCTION: Ask the children to name some machines that help us overcome gravity. Have them make a chart showing the machines and observe similarities among them. Do they notice any similarities? Can they list them? What gives each of these machines the needed energy to overcome the Earth's gravitational pull? Which can supply enough energy to travel deep into space?

Explore with the children the sources of energy for various machines with which they may be familiar. On what principle do they operate? Which of these energy sources do the children



think would be feasible to power a space vehicle? Which would not? Why not?

Could a jet airplane go into space? *(No.)* What does a jet engine need to operate? *(Oxygen.)* Any engine that uses a fuel such as gasoline or kerosene must also have a source of oxygen (oxidizer) available to combine with the fuel. Kerosene and gasoline use oxygen from the atmosphere. Is there oxygen in space? *(No.)*

Machine	Energy source
Automobile	Gasoline and oxygen
Jet airplane	Kerosene and oxygen
Nuclear submarine	Nuclear (uranium)
Locomotive	Diesel fuel and oxygen
Electric motors	Electricity
Cordless electric razors	Electric storage batteries
Steam engine	Steam

To supply answers to these questions, let the children place a candle (fuel) inside a jar in an upright position and light the candle. Then have them place the lid tightly on the jar and observe what happens to the candle's flame. *(It should go out in a short time.)* Why? *(The candle uses some of the oxygen in the jar to burn.)* The candle serves as the fuel to combine with the oxygen in the air inside the jar. If a jet engine approaches the outer limits of the atmosphere, where the oxygen supply becomes slight, what will happen? *(The fuel will have nothing with which to combine and therefore will not burn.)*

Pose the question, "Where can an engine obtain a supply of oxygen in space?" *(To venture into space, where there is no oxygen, it must take a supply of oxygen along.)* Explain that this might be in the form of pure oxygen or oxygen in combination with other elements. Many compounds in our environment contain oxygen. In some cases this oxygen in compounds can be taken into space along with the fuel (kerosene).

Have the children pour about 1 inch of hydrogen peroxide into a small bottle and add a teaspoonful of ordinary baking soda. Then ask them to place a piece of cardboard over the top of the jar and set it aside for about five minutes. Explain that the tiny bubbles escaping from the peroxide are bubbles of oxygen. Light a broom straw or wooden splinter. Blow out the flame so the straw or splinter just glows. Put the glowing straw or splinter into the bottle and notice what takes place. *(The straw should burst into flame.)*

Extending Ideas: The children will probably be aware that many substances in our environment contain oxygen. Explain to them that sometimes this oxygen is easily obtainable, as it is from hydrogen peroxide. At other times it is held so strongly in combination with other elements that it is not so easily freed. Ask the children to list some other substances that contain oxygen. Could these be used as sources of oxygen in the space engine? Can the children suggest reasons why a propeller or jet engine would not work in space? *(No air is available for the propellers or jets to use.)* The children should deduce that oxygen must therefore be taken into space to use as an oxidizer for the fuel. (An oxidizer is any rocket-fuel compound that supports the combustion of the fuel.) Both oxygen and fuel must be taken aboard the spacecraft. How can oxygen be stored in a space small enough for it to be placed in a rocket? *(One way is to cool it and compress it into a liquid. Liquid oxygen is called* LOX.)

Learnings: Many machines help us to overcome gravity. A great deal of energy is required to overcome gravity completely. An engine that burns fuel must take its own oxygen into space with it, for there is no oxygen in space.

Summing Up Ideas: In this section, the children were introduced to gravity as something that makes it difficult for man to get into space. They learned of gravitational attraction and how it pulls everything toward the center of the Earth. They learned how gravitational attraction can be overcome by the application of a sufficient and opposing force. In addition, they saw how some machines help us to overcome gravitational attraction and that, if the engine that drives the machine needs oxygen to burn a fuel, oxygen will have to be carried into space along with the fuel for the machine.

HOW DOES A ROCKET WORK?

The principle of rocket and jet engines is based upon Sir Isaac Newton's third law of motion, which states that for every action, there is an equal and opposite reaction. This principle may be illustrated and experienced in a wide variety of ways. It may be helpful for the children not only to identify situations during which this principle is at work but also to experience action–reaction themselves.

Rockets move forward because of the thrust of expanding gases produced within the rocket engine. The fuel inside the rocket combines with the oxidizer and causes a powerful combustion. This produces a tremendous quantity of gases inside the rocket engine. The release of these gases is controlled so that they will escape in only one direction, thus moving the rocket in the opposite direction.

Some of the factors that affect a rocket's effectiveness are *thrust, specific impulse, mass ratio,* and *staging.*

Thrust is the push a rocket receives from the rapidly escaping gases passing through the exhaust nozzle. The amount of thrust depends upon how much gas (mass) passes through the nozzle, and how fast (velocity) it passes through. The more gas present and the faster it escapes, the greater the thrust will be.

Specific impulse is a measure of the amount of thrust a rocket propellant produces. More specifically, it is the thrust produced by a unit amount of the propellant per unit time, usually one second.

Mass ratio is the ratio between the rocket's total weight and its weight after the fuel has been consumed. The higher the mass ratio, the greater the speed the rocket will achieve, since a high mass ratio shows the rocket has been able to carry and burn a large amount of fuel.

Staging is the construction of the rocket in a number of sections, each with its own engine. The rocket engines ignite in succession, with the one previously used falling off. One big advantage of the staging principle is that unnecessary weight is separated from the rocket as soon as the weight no longer serves any useful purpose. This improves the mass ratio of the latter stages.

ACTIVITY 52 (x,y,z)

DISCOVERING ACTION–REACTION

Purpose: To introduce the children to Newton's third law of motion

Concept to be developed: Rocket engines work on the principles described by Newton's third law of motion, which states that for every action, there is an equal and opposite reaction.

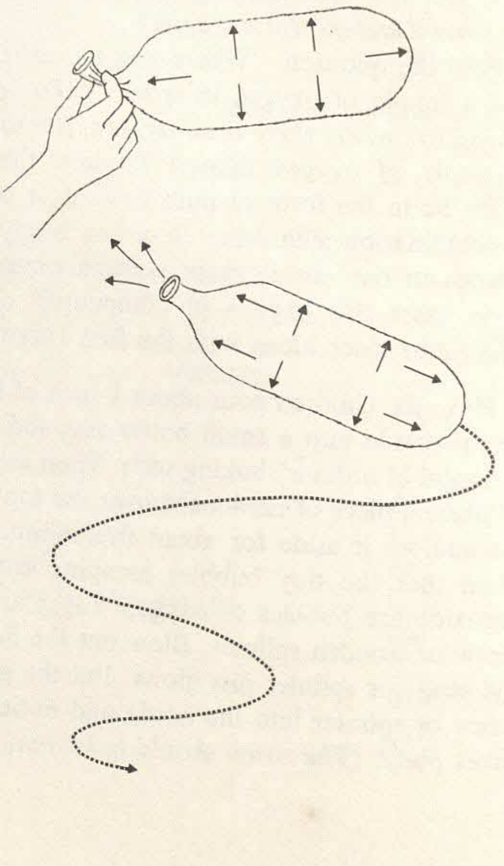
Materials needed:

2 pairs of roller skates
Large ball
Rubber balloon

INTRODUCTION: Have a child put on a pair of roller skates and throw a ball over his head to another child. Does the child on roller skates move? In what direction? Why? Try the same thing with both children on roller skates as they play catch. What happens? (The children should move apart.) Can the children devise other demonstrations of this phenomenon?

A rubber balloon can serve as a simple rocket engine. Examine a balloon with the class. Then have a child inflate it, hold it above his head with the end closed, and then release it. Let the children observe what happens. *(The balloon will probably fly across or around the room.)* Why? *(The gas inside the balloon is exerting pressure in all directions. When the balloon is released, the air is allowed to escape out one end. Since the action of the escaping air is in one direction, the balloon will travel with equal force in an opposite direction.)*

Extending Ideas: Explain to the children that air under pressure in a balloon does not exert enough energy to make the balloon travel a great



distance. Pose the question, "How can the amount of energy be increased?" *(One way is to increase the amount of gas.)* What will happen if too much air is placed in a balloon? Why does the balloon explode when a great amount of air is placed inside? What could be done to prevent this? *(One way would be to have a balloon with stronger walls.)* Try to obtain a balloon made of more durable rubber. See if more air can be placed inside. Can the children suggest what materials a real rocket might be made of? What would be the requirements of such a material?

Ask the children to collect pictures of, and to explain examples of, the action–reaction principle at work in a variety of ways. For example, have them explain the following:

Lawn sprinklers: Water rushing out in one direction causes motion in the opposite direction.

Rifle or cannon firing: A rifle or cannon fired in one direction causes a "kick" in the opposite direction.

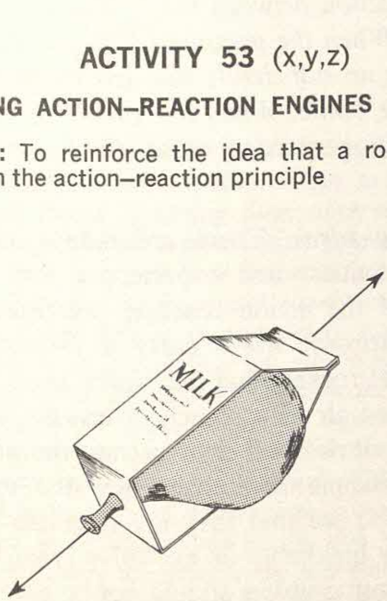
The children can experience the action–reaction principle themselves. When they ride in a car, bus, train, or airplane, and it starts or speeds up, they can feel the backward thrust when the vehicle moves forward. Can they identify other instances when they have experienced the action–reaction principle?

Learnings: For every action, there is an equal and opposite reaction. This is the principle of the rocket engine.

ACTIVITY 53 (x,y,z)

BUILDING ACTION–REACTION ENGINES

Purpose: To reinforce the idea that a rocket engine works on the action–reaction principle



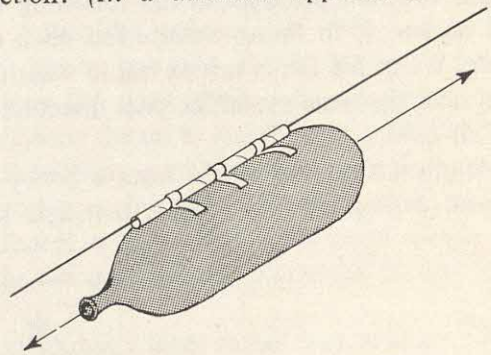
Concept to be developed: For every action, there is an equal and opposite reaction.

Materials needed:

- Milk cartons
- Rubber bands
- Balloons
- Tub of water
- Straws
- Cellophane tape
- Glass tubes
- Wire
- Electric fan
- Roller skates
- Sponge rubber or cloth
- Carbon dioxide cartridges and puncturing needle
- Cup hooks
- Bottles (flat)
- Balsa wood dowels
- Cork
- Baking soda
- Vinegar
- Round pencils or dowels (1/4 inch)

Have groups of children build the following action–reaction engines:

Balloon-powered boat: Have a child cut a milk carton in half lengthwise, and puncture a hole in the bottom side near the edge. Next, he should insert a glass tube into the hole and attach the balloon to it with a rubber band. Then another child can inflate the balloon and place the boat in a tub of water. Does it move? *(Yes.)* In what direction? *(In a direction opposite to that in which the air is escaping.)* Can the children note the difference in speed when the open end of the glass tube is under the surface of the water? *(The "boat" moves more quickly when the tube is out of the water.)* Why? *(The air escapes more quickly.)*



Balloon-powered rocket: Using cellophane tape, a child can attach a drinking straw to the side of a long balloon. Then he should pass a thin wire through the straw and attach one end of the wire to a school fence, post, or door handle. Next, have him pull the wire taut and attach the other end to an object on the opposite side of the room or yard. After inflating the balloon he should release it suddenly. Let the children observe the balloon's movement in relation to the direction of the escaping air.

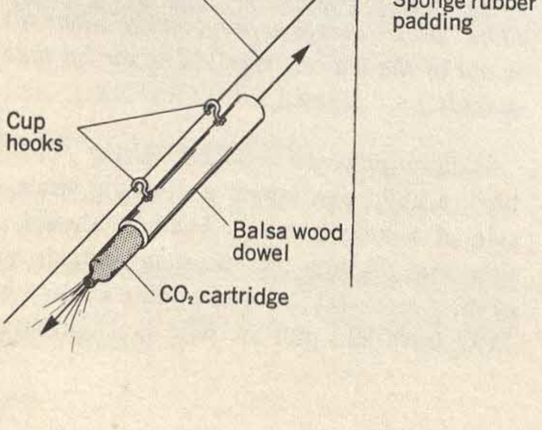
Have the children devise other vehicles that use the air escaping from a balloon as the source of power. In each case, what is the vehicle's direction of movement in relation to the direction of the escaping air? *(Explain that this is what is meant by action and reaction. The action of the air rushing out one end of the balloon causes a reaction, or movement, in the opposite direction.)*

The simple machines the children can design by using balloons as the source of power are not very powerful, however. They do not go far or travel very fast. Pose these questions for the children to consider: How can more powerful and efficient machines be built? What happened when too much air was placed in the balloon? Would a metal container be strong enough to allow the storage of more gas under greater pressure? If the gas escaped more rapidly, would the rocket go farther?

The children can devise other types of machines in which there is a more efficient use of the action–reaction principle in the following ways.

One way is to tie an electric fan on a roller skate. When the fan is turned on, in what direction does the skate move? In what direction does the air move?

Another way is to obtain from a hobby store several carbon dioxide (CO_2) cartridges and a spring-powered puncturing needle to pierce the ends of the cartridges. Many types of rocket ships (air frames) for the cartridge may be constructed using mailing tubes, balsa wood, or plastic containers. Ask the children to design and construct their own rocket ships. (Elements of safety must be kept in mind when choosing materials and propellants.)



Suggest that one way to construct a rocket ship is to hollow out the end of a balsa wood dowel to hold a CO_2 cartridge. Attach two cup hooks in the top of the dowel. String a wire taut across the schoolyard, and hang the rocket on it. Place the CO_2 cartridge in the end of the dowel, and puncture it. Be sure the other end of the wire is padded with sponge rubber or cloth so the balsa wood rocket will cause no damage on impact.

Suggest to the children that another way of increasing rocket energy is to use a fuel that will generate a large amount of expanding gas. To do this, they should obtain a flat bottle, some round pencils or ¼-inch dowels, some vinegar, baking soda, and a cork. Have them place one tablespoon of baking soda in the bottle, add 2–3 ounces of vinegar, and place the cork loosely in the opening. Ask them to lay the flat side of the bottle on the dowels and observe the action of the cork and the reaction of the bottle. *(The cork pops out in one direction, and the bottle rolls along the dowels in the opposite direction.)* Why? *(The children can see the bubbles in the vinegar. The bubbles are carbon dioxide gas, generated in the reaction between the baking soda and the vinegar. When the pressure of the gas in the bottle builds up sufficiently, the gas forces the cork out of the bottle. When the gas flows out of the bottle, action–reaction causes the bottle to move forward.)*

Extending Ideas: There are many demonstrations, activities, and experiences that are examples of the action–reaction principle. Hobby and department stores carry a variety of toys and model rockets that use water, solid fuels, or compressed air as a source of energy. The children can devise and demonstrate the action–reaction principle themselves. However, care must be taken to see that they use materials that are not easily breakable or explosive. Match heads, fuels, or gun powders should not be used without adequate supervision. There may be a local student chapter of the American Institute of Aeronautics and Astronautics or an amateur rocket organization in your area that has facilities for constructing and launching more complicated rockets with liquid or solid propellants. It would be well to contact such a group to seek guidance, assistance, and direction in the proper construction or use of launch facilities and to learn precautionary measures. Sometimes fire departments have regulations prohibiting the firing of rockets. Special licenses may also be needed.

Toys, models, and student-made rockets usually achieve limited heights. However, with the addition of longer-burning fuels, better rocket shapes, more efficient fuels, and lighter materials, a rocket can be constructed that can overcome the Earth's gravitational pull sufficiently to go into orbit around the earth or at least to achieve a high altitude.

Learnings: The energy of an expanding gas can cause a vehicle to move. This movement can be explained by the principle of action–reaction.

ACTIVITY 54 (x,y,z)

DISCOVERING THRUST

Purpose: To show the way in which the thrust of a rocket propellant is measured

Concept to be developed: The thrust of a rocket propellant is the amount of force it produces.

Materials needed:

Garden hose
Rotary lawn sprinkler
Toy rocket or balloon
Balance or fulcrum scale
Weights

INTRODUCTION: On the school playground or at their homes, help the children begin to learn the meaning of thrust *by letting them observe and feel the thrust produced when water passes through a garden hose. Lay the hose across a large expanse of lawn. Connect the hose and slowly turn on the water, until the faucet is completely open. Have children observe the action of the hose. As the amount of water that passes through the hose increases, the hose should begin to move. In what direction does it move? The children should hold the hose and feel its motion forward. Why does the hose tend to move? Do the children notice any difference as more water passes through the hose?* (The more water, the greater the movement of the hose.) *Attach a rotary lawn sprinkler to the hose. Gradually turn on more water. Notice the speed of the lawn sprinkler. Does it move faster or slower as the amount of water increases?* (Faster.)

The children may wish to contact the water company to find out the water pressure in their particular location. They may also wish to measure the inside diameter of the hose. Will a larger hose cause the sprinkler to turn faster? (Yes.) *How is water pressure measured?* (Water pressure is measured in pounds.) *Point out to the children that the thrust of a rocket is also measured in pounds. This can be shown in the following way.*

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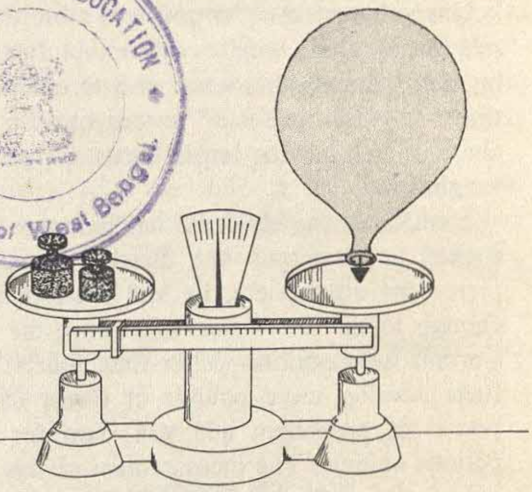
Thrust may be measured with a balance scale. Have the children inflate a balloon (or turn on a toy rocket motor) and hold it directly over the scale. Adjust the scale so that several ounces of weight are on one side. Firmly holding the balloon over the other weight pan, release the nozzle, allowing the air to escape against the balance pan. How many ounces or pounds of thrust does each rocket engine or balloon exert on the scale? Experiment with various amounts of weight to find the amount of thrust exerted by the escaping gases.



Explain that a large rocket may produce 150,000 to 500,000 or more pounds of thrust. Have the children look in newspapers or in books about rockets to find out how many pounds of thrust various rocket engines produce. Then ask them to make a chart showing the name of the rocket, the weight of the rocket, and the amount of thrust in pounds it produces.

Develop with the children the idea that if a rocket weighs 5 tons, this means that the Earth's gravity is pulling down on this rocket with 5 tons of force. In order for the rocket to rise, it must overcome that pull of 5 tons toward the center of the Earth. Therefore, the rocket's thrust must exceed 5 tons (10,000 pounds) in order to rise. Ask the children, "If a rocket weighed 500,000 pounds, how much thrust would it need to rise? What if it weighed a million pounds?"

Extending Ideas: Ask the children which of the following rockets they think would achieve the greatest height. Why?

Rocket weight	Thrust
500,000 pounds	500,500 pounds
500,000 pounds	750,000 pounds
500,000 pounds	1,000,000 pounds

Naturally, rockets that produce more thrust in relation to their weight will travel faster and higher. Some children may wish to compute the thrust-to-weight ratios of various rockets on the chart. Which has the largest thrust in relation to weight?

Explain to the children that in order for the rocket to overcome the Earth's gravity and pierce the atmosphere, its fuel must burn long enough to lift the rocket high above the Earth. Certain fuels perform better than others. Better fuels develop more pounds of thrust for each pound of propellant and will burn for longer periods of time. The measurement of this aspect of a fuel's performance is called its *specific impulse.*

For example, if 1,000 pounds of rocket propellant produces a thrust of 5,000 pounds, and it burns in 60 seconds, what is the specific impulse of this fuel?

$$\text{Specific impulse} = \frac{\text{thrust} \times \text{burning time}}{\text{weight of propellant}}$$

$$\text{Specific impulse} = \frac{5{,}000 \text{ pounds} \times 60 \text{ seconds}}{1{,}000 \text{ pounds}}$$

$$\text{Specific impulse} = \frac{300{,}000 \text{ pound-seconds}}{1{,}000 \text{ pounds}}$$

$$\text{Specific impulse} = 300 \text{ seconds}$$

What would be the specific impulse of a rocket that produced 1 million pounds of thrust and was loaded with 75,000 pounds of fuel that burned for 120 seconds?

Learnings: The thrust of a rocket is a measure of the energy of its fuel. The specific impulse is a measure of the amount of thrust a propellant will produce for each pound of propellant burned per unit time.

ACTIVITY 55 (z)

DETERMINING MASS RATIO

Purpose: To develop the concept of mass ratio

Concept to be developed: The mass ratio of a rocket is a measure of the final speed it will achieve—the higher a rocket's mass ratio, the greater will be its speed.

Materials needed:

Water
Water rocket
Scale

INTRODUCTION: The children have now learned that it takes a certain amount of energy to cause a rocket to leave the ground. But what factors affect the final speed of the moving rocket? Develop with the children that mass ratio is involved; explain its meaning, using information contained in the beginning of this section. The following Activity will help the children understand this term.

The children can determine the mass ratio of a toy rocket by weighing it before it is launched and after it returns to Earth, and comparing the difference in weight. A water rocket can show this well. Weigh a rocket filled with water. Launch it, and weigh it again. What was the weight of the water? If the rocket weighed 1 pound before launch and ½ pound after launch, the rocket would have a mass ratio of 2.

$$\text{mass ratio} = \frac{\text{weight before}}{\text{weight after}} = \frac{1}{1/2} = 2$$

Ask: Is water a good propellant? *(It is not very good because of its heavy weight.)* Lighter-weight fuels are more desirable because they produce a higher mass ratio. Can the children think of some lightweight elements that might be used for fuels? *(Oxygen, hydrogen, and fluorine.)*

Learnings: The mass ratio of a rocket is its weight before launching divided by its weight after it returns to the Earth. The greater a rocket's mass ratio, the greater will be its final speed.

ACTIVITY 56 (x,y,z)

LEARNING ABOUT ROCKET PROPELLANTS

Purpose: To familiarize the children with the different types of rocket propellants

Concept to be developed: There are several types of rocket propellants, liquid, solid, and hypergolic.

Materials needed:

None

Launch vehicle	Stages	Propellant fuel and oxidizer	Thrust	Remarks
Scout	5	Solid	366,600	Sounding rocket
Atlas	1	Liquid	367,000	Used in Mercury Program
Centaur	2	H_2–LOX	397,000	First rocket to use liquid hydrogen
Saturn V	3	Liquid	7,500,000	Most powerful booster

INTRODUCTION: The children will know by now that in order to leave the Earth, rockets must have vast amounts of energy. They have learned that this energy is supplied by the escaping gas produced by various kinds of propellants. Explain that there are several kinds of propellants; each has advantages and disadvantages. Other types of energy sources are being explored.

Some fuels are *solid propellants*—the fuel and the oxidizer are packed together in a solid state. (Actually, it is more like putty.) When they are brought to a high enough temperature by a spark, they ignite, and a gas is released.

Liquid propellants, such as kerosene and liquid oxygen (LOX), are ignited when they are combined to form a gas. Perhaps the children would like to make a chart showing various liquid fuels and the oxidizers with which they combine:

Fuel	Oxidizer
Aniline	Nitric acid
Hydrazine (N_2H_4)	Nitric acid Nitrogen tetroxide (N_2O_4)
Kerosene	Oxygen
Alcohol	Oxygen

Hypergolic fuels do not need a spark to ignite them. They combine automatically when the fuel and the oxidizer are together.

Suggest that the children make a chart showing the various names of launch vehicles, the number of stages in each, the type of propellant, the amount of thrust, and other important information. They may wish to draw diagrams of each launch vehicle, explaining its parts and power source.

Extending Ideas: The children may wish to explore the principles of nuclear and electric propulsion systems. Possibly they can explain some of the advantages and disadvantages of each. Nuclear propulsion engines could send a 100-ton spacecraft to the Moon and back, using about 5 tons of propellant. A chemical rocket would need over 9,000 tons of fuel. Explain to the children that the problems of nuclear rockets include the tremendous amount of heat that they must generate, their large size and weight, and the problems of radiation if the spacecraft is manned.

Electric rockets can produce a high specific impulse of over 2,000 seconds (compared to 250 seconds in chemical rockets). However, generating electricity in space requires complex and bulky equipment. (You may wish to explore electric generators at this point.)

Discuss with the children the various power sources available. Encourage them to speculate as to other possible power sources: for example, solar (radiant) energy.

Learning: Rockets are propelled by different types of fuels.

ACTIVITY 57 (y,z)

DESIGNING A ROCKET

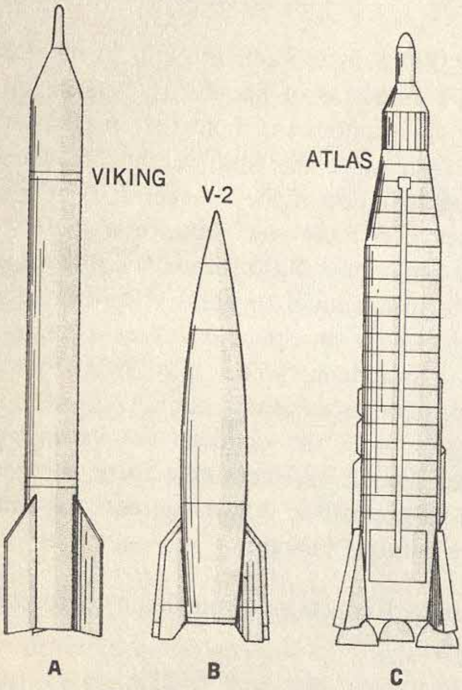
Purpose: To illustrate the reasons for shaping rockets in a specific manner

Concept to be developed: Rockets must be designed to reduce air resistance and the frictional forces they meet in the atmosphere.

Materials needed:

- Balsa wood blocks
- Woodworking tools
- Tub of water
- Paper
- Scissors
- Balloons
- Wires or strings

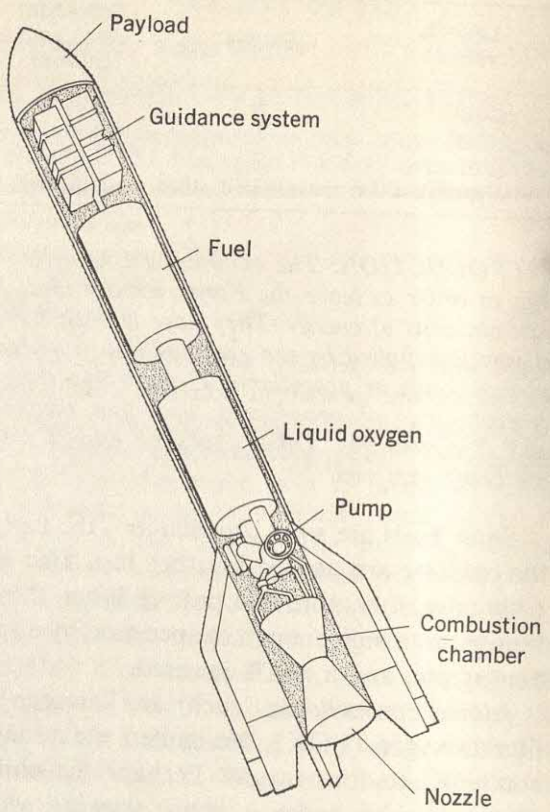
INTRODUCTION: The children are now ready to understand that efficient rocket performance depends also on the shape of the rocket and of the nozzle through which the gases escape. They may enjoy drawing, modeling, and building rockets of various sizes and shapes. Help them to discover the similarities and characteristic shape of rockets. Ask them to consider why the rockets are shaped this way. How does this shape help them to move more easily through the atmosphere? The children will discover that the rockets are shaped the way they are to help *overcome the resistance and friction* of the atmosphere. As the rocket moves through the air, the pointed nose pierces the air like a wedge and helps the rocket glide more easily. This same principle can be observed on the prow of a ship, the nose of an airplane, and the shape of a bullet. Can the children find other examples?*



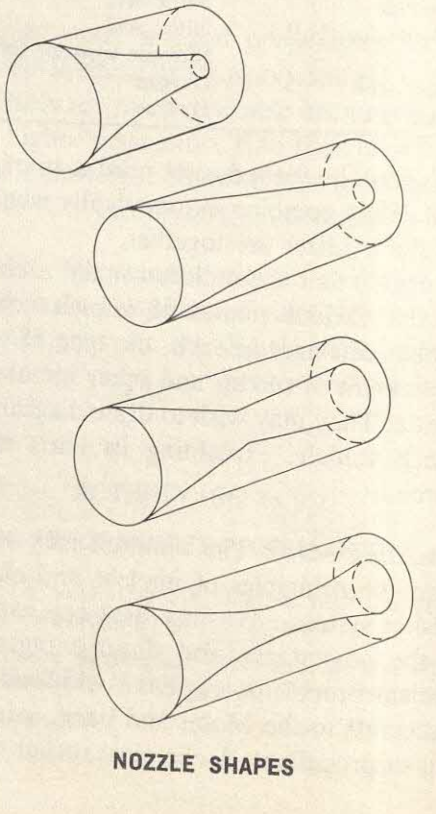
Have several children design and carve several rocket shapes from balsa wood. Let them experiment to find the most efficient shape by floating each in a tank of water. As the models are moved across the tub, have the children observe the shape of the ripples produced by each. Which model moves fastest?

Attaching paper nose cones of various shapes to a balloon on a wire (see Activity 53) will help the children to see which model travels fastest across the wire. The children may wish to carve rockets of various shapes that will use CO_2 cartridges (see Activity 53). The children can also experience this as they hold their hands in various positions out the window of a moving car.

Point out that the escape nozzle through which the expanding gas passes also plays an important part in the rocket's function. The children may wish to examine the shapes of various rockets' nozzles. How are they similar? How are they different?



Let the children carve escape nozzles. The nozzles may be placed in the necks of balloons to determine their effect on the velocity and thrust of the escaping air.



NOZZLE SHAPES

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*For a discussion of friction and air resistance, see *Motion*, by Lois Dunn (Investigating Science with Children Series; Darien, Conn., Teachers Publishing Corporation, 1964).

Extending Ideas: Suggest that some children report on the lives of various men who have contributed to our understanding of launch vehicles, including:

Hermann Ganswindt
Robert Goddard
Hermann Oberth
Bruce Sage
Wernher von Braun
Theodor von Karman
Konstantin Ziolkovsky
André Bing

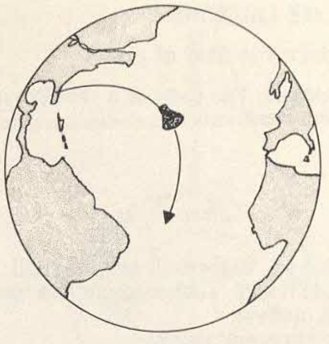
Learnings: The shape of a rocket alters the effects of friction and air resistance upon it. The nozzle's shape affects the amount of thrust the expanding gases can produce.

Summing Up Ideas: In this section, the children were introduced to the factors by which rockets launch satellites into orbit. They learned of the principle of action–reaction, which explains how expanding gases cause the rockets to move. They learned the meaning of the terms thrust, mass ratio, specific impulse, and staging. They learned about the solid and liquid propellants that burn inside the rockets to produce the exhaust gases. In addition, they were introduced to the idea of why rockets are shaped as they are and of the frictional forces and the air resistance that rockets must overcome in passing through the Earth's atmosphere.

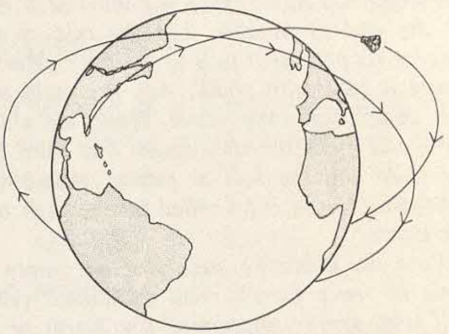
WHICH WAY SHALL WE GO?

When a launch vehicle is powerful enough, it can lift a *payload,* such as an *artificial satellite, deep space probe,* or *manned capsule,* off the Earth. How can the spacecraft be controlled so that it will go into the proper flight path? Depending on its speed, angle of launch, and guidance system, the spacecraft will either go up and fall back to the Earth, circle the Earth, or go into a deep-space trajectory.

Some spacecraft are sent just high enough to gather information in the upper atmosphere and then return to the Earth. Others are intended to circle the Earth in an elliptical orbit. Others will be sent near or to the Sun, the Moon, or the other planets.



SUBORBITAL



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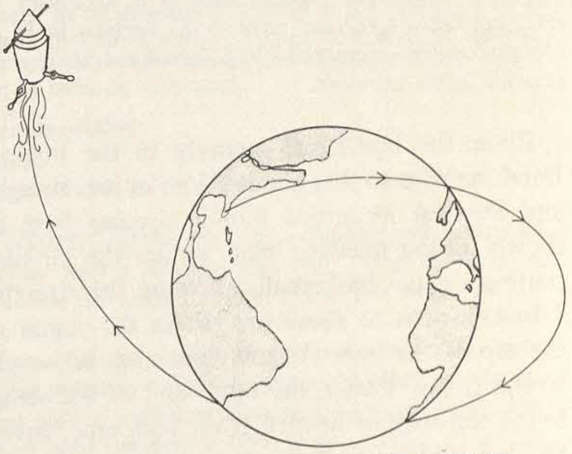


DEEP SPACE

Spacecraft that return to Earth without entering outer space are called *suborbital.* Sounding rockets, intercontinental missiles, and the two initial manned flights—by Alan Shepard on May 5, 1961, and Virgil Grissom on July 21, 1961—were suborbital. Actually, when a child throws a ball into the air or shoots an arrow, he is launching a suborbital flight. If a child could throw a ball out far enough (100 miles or so) and fast enough (about 17,500 miles per hour), it would fall around the Earth instead of back to the Earth's surface.

ACTIVITY 58 (x,y,z)

MAKING A SATELLITE LAUNCHER*

Purpose: To introduce the idea of orbits

Concept to be developed: The path of a satellite around the Earth is called its orbit.

Materials needed:

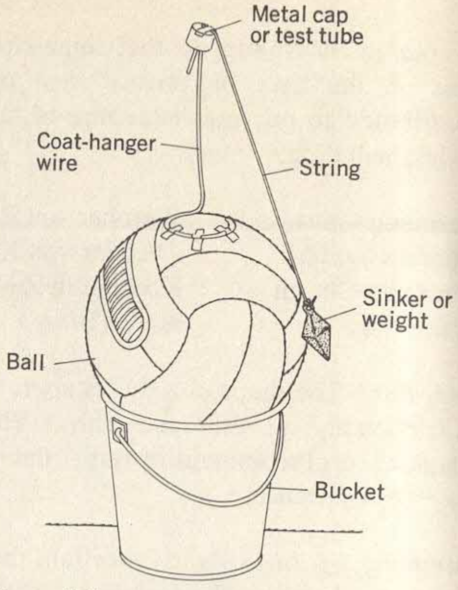
- Ball
- Table
- Chalk
- Large ball, such as a basketball or volleyball
- 2-foot length of stiff wire, such as a clothes hanger
- String (about 18 inches)
- Lead sinker or other small weight
- Test tube or object of similar shape, such as the cover of a lipstick tube
- Masking tape
- Bucket or large bowl

INTRODUCTION: Have a child roll a ball gently off the end of a table. Let the rest of the group observe its path as it falls to the floor. Mark the spot where it falls with chalk. Ask the child to roll the ball again, this time faster. Have the children observe and mark the spot again. The third time, have the child roll the ball as fast as possible. Ask the children, "Could it be rolled fast enough to 'fall' off the Earth?"

Pose the following questions that apply this principle to space travel: Why do launch vehicles that will send spacecraft around the Earth or into deep space need to be bigger and more powerful than those for suborbital flights? Why is it necessary to have rockets of various sizes to do various tasks in the exploration of space? The following Activity may provide some answers.

Place the basketball securely in the bucket. Bend the wire so that about 1 foot of it is straight and the rest is curved into a circular base as shown. Using masking tape, secure the circular portion on the basketball, allowing the straight, 1-foot portion to stand upright in the center of the top of the ball. Attach the sinker or weight to the string. Fasten the other end of the string to the test tube or lipstick cover with tape. Invert the test tube or lipstick cover on top of the upright wire.

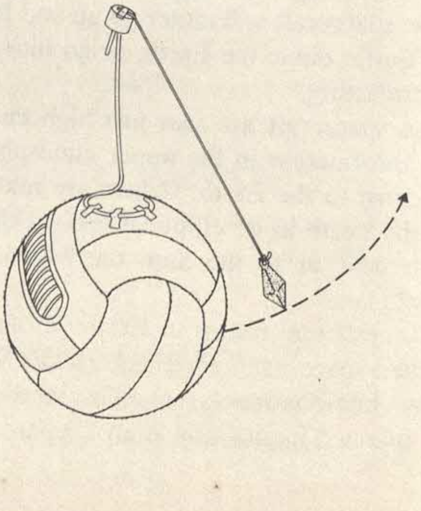
Explain that the basketball represents the Earth, and the sinker represents the satellite. All that it takes to set the sinker into motion in any direction is the tap of a finger. Let the children find out what happens when the satellite is launched in the following different ways:



1. With a slight tap, push the sinker up and away from the surface of the ball, as shown. What happens? *(The sinker moves up and then falls right back to the starting point. This is how an object travels when it is projected at low speed straight up from the Earth.)*

2. With a slight tap, push the sinker off the surface of the ball at an angle, as shown. Show by a diagram what happens. *(The sinker moves away from the ball and then falls back at some distance from the starting point. The distance spanned depends upon the angle of launching and upon the forcefulness of the tap.)*

3. With a stronger tap, push the sinker off the surface of the ball at an angle, as shown. Make a diagram of the orbit. *(The sinker moves away from the ball, circles it, and lands near the starting point. Evidently, a* complete *orbit passes through the starting point of the orbit.)*



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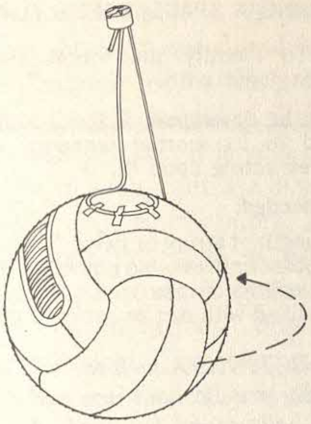
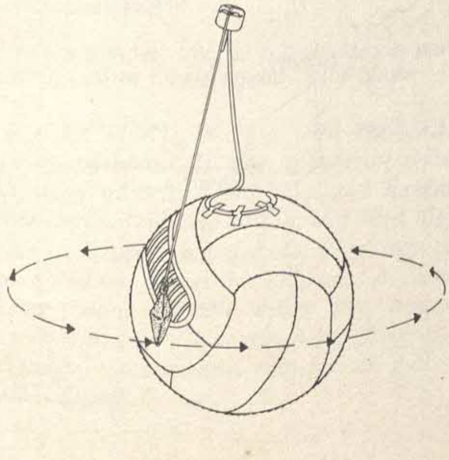
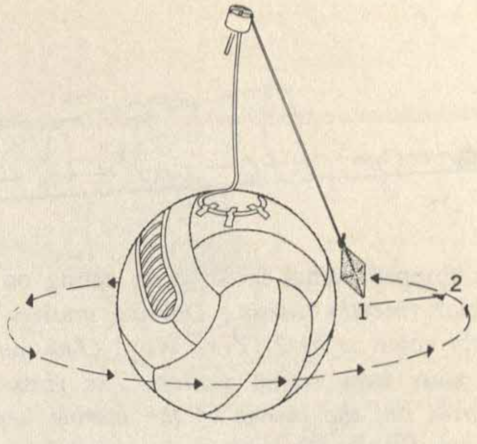
*"Orbits for your Satellite," by Harry Milgrom, *Elementary School Science Bulletin*, March, 1960.



4. With one tap, push the sinker up from the surface of the ball. With another tap, push the sinker in a direction that is parallel to the surface. Is this orbit different from the one in Step 3? *(The sinker goes into orbit, circling the ball without touching it. Now, since the starting point of the orbit is off the surface, the orbit is completely in "space" and makes no contact with the ball at any point.)*

Extending Ideas: Explain to the children that, in its orbit, the sinker is at varying distances from the ball. The smallest distance is called the *perigee* of the orbit. The biggest distance is called the *apogee* of the orbit. Because of friction between the metal cap and the wire, the size of the orbit gradually decreases until the sinker "plunges" back to the surface of the ball. In the same way, friction with the thin atmosphere eventually causes a real satellite to fall back to Earth and burn like a meteor as it passes through the denser atmosphere on its downward journey.





If the school has a tether ball, a similar activity may be performed with it.

Learnings: The path of a satellite is called its orbit. The size of the orbit depends on the velocity of the spacecraft.

ACTIVITY 59 (x,y,z)

DISCOVERING INERTIA

Purpose: To find out why a satellite assumes the orbit that it does

Concept to be developed: Inertia is the tendency of a body at rest to remain at rest or of a body in motion to remain in motion **in the same direction** unless acted upon by some outside force.

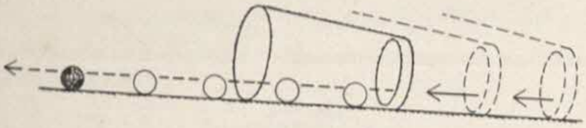
Materials needed:

Glass
Small rubber ball or marble

INTRODUCTION: Now the children are ready to consider why a satellite goes into orbit. Explain to them that Sir Isaac Newton's first law states that a body remains at rest or travels with constant velocity in a straight line unless an external force acts upon it. This property is called inertia. *In other words, an object that is set in motion will continue with that motion until something stops it or changes its direction. This has direct bearing upon the performance of a satellite in orbit, as the children will see in the following Activity.*

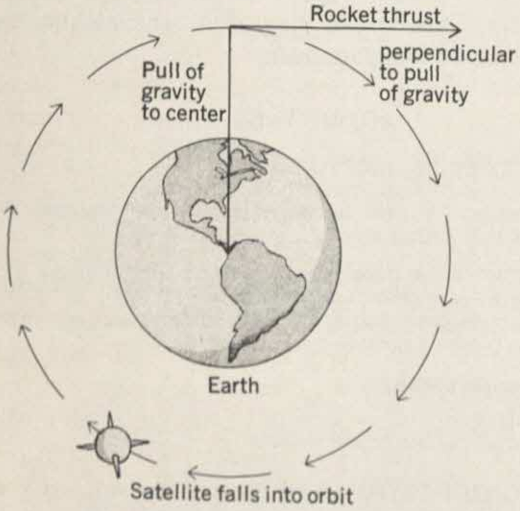
Have a child place the marble or ball inside the glass and, with the glass on its side, move it swiftly along the surface of a table. Let him stop the glass suddenly and observe the motion of the marble.

Ask the children why the marble continued to move across the table even after the glass had



been stopped. What forces were acting on the marble? *(Mostly inertia.)* Did the marble ultimately come to rest? *(Yes.)* Why? *(The marble and glass were set in motion. The glass was stopped, but the inertia of the marble kept it moving. Finally the force due to friction slowed the marble to a stop.)*

Now make the point that a rocket takes the satellite to a point in space in a similar manner.


Rocket thrust
Pull of gravity to center
perpendicular to pull of gravity
Earth
Satellite falls into orbit

There the rocket gives the spacecraft enough speed (about 17,500 miles per hour) to remain in orbit. The rocket also gives the spacecraft direction. The direction should be about perpendicular to the pull of gravity. The combined effect of the spacecraft's inertia of motion and the gravitational pull of the Earth results in a circular path of the spacecraft around the earth.

Learning: Inertia is the tendency of a body at rest to remain at rest or of a body in motion to continue in motion (in the same direction and at the same speed) unless acted upon by an external force.

ACTIVITY 60 (x,y,z)

DETERMINING A SPACECRAFT'S FLIGHT PATH

Purpose: To identify the forces that determine a spacecraft's flight path

Concept to be developed: A spacecraft's flight path is determined by its inertial tendency and the gravitational forces acting upon it.

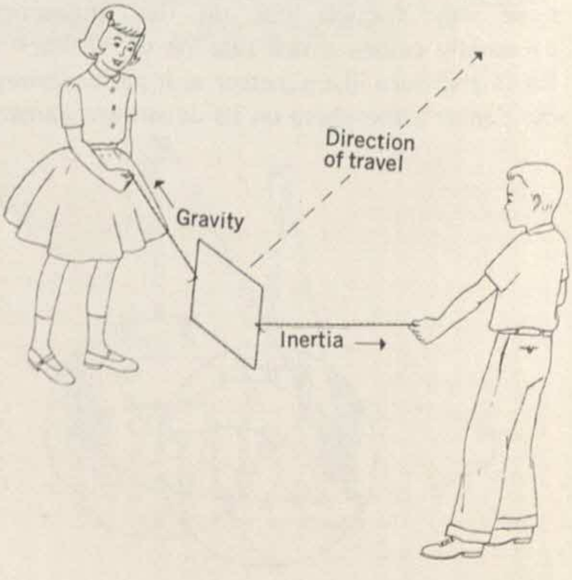
Materials needed:

3-foot length of string or twine
Ball or other unbreakable object
2 equal lengths of rope
Carton (filled with dirt or rocks to give it weight)

INTRODUCTION: Attach the ball to the end of the string. Have a child hold one end of the string and swing the ball around his head. Ask the children to observe in what direction the ball moves. Ask what the string represents. (Gravity.) *While the ball is in motion, suggest that the child release the string. (Be careful to prevent the ball's hitting anyone!) Have the class observe the direction in which the ball travels. Ask the children, "In what direction would the satellite travel if there were no gravity?"*

Attach a length of rope to each end of the weighted box. Ask one child to pull on one rope in one direction. Have another child pull the other rope in a direction that is at a 90° angle to the pulling of the first child. In what direction does the box travel?

Discover what happens if the 90° angle is changed; if one child pulls with more force than the other; if one child pulls faster than the other. In each of these cases, the direction of the box's motion will be changed.



Likewise, the path that the satellite takes is dependent upon the force and direction that the rocket initially exerts upon it. If the satellite is moving at just the right speed and in the precise direction to balance the Earth's gravitational pull, the spacecraft will follow a circular orbit around the Earth. However, it is very difficult to make a rocket go in such a precise direction and with such exact speed. Furthermore, it may be desired that the satellite travel at varying distances from the earth so as to gather information about conditions at various altitudes. Therefore, orbits are elliptical. The shape and size of the ellipse depend on the speed and direction of the spacecraft.

If the spacecraft travels at less than 17,500 miles per hour, it will be suborbital. If it achieves a speed faster than 17,500 miles per hour (orbital velocity), it will go into orbit around the Earth. If the launch vehicle can achieve a speed of approximately 25,000 miles per hour, it will escape the Earth's gravitational force and go into deep space, perhaps to the Moon or the other planets.

Learning: The two factors that determine a spacecraft's flight path are its inertial tendency and the gravitational forces acting upon it.

ACTIVITY 61 (x,y,z)

ILLUSTRATING FLIGHT PATHS

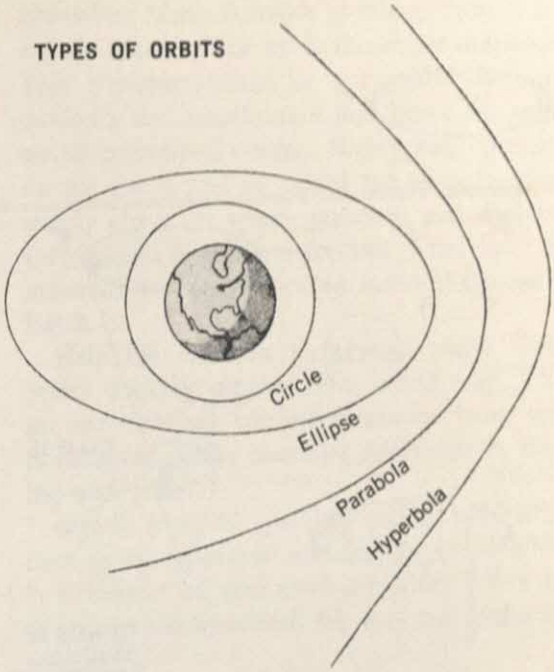
Purpose: To show the paths in which spacecraft may travel

Concept to be developed: A spacecraft may travel in one of four possible flight paths—a circle, an ellipse, a parabola, or a hyperbola.

Materials needed:

- Cone-shaped paper cups
- Construction paper
- Scissors
- Tempera powder, ink, or rubber stamp pad
- Cutting tool or single-edged razor blade

INTRODUCTION: Discuss with the children the following problem: If the spacecraft escapes the Earth, what trajectory will it follow? Explain that a satellite may follow one of four different flight paths: a circle, *an* ellipse, *a* parabola, *or a* hyperbola. *All Earth satellites travel in ellipses. A vehicle that achieves about 25,000 miles per hour (escape velocity) will go into a parabolic flight path. If it goes faster than escape velocity, it will follow a hyperbolic path.*



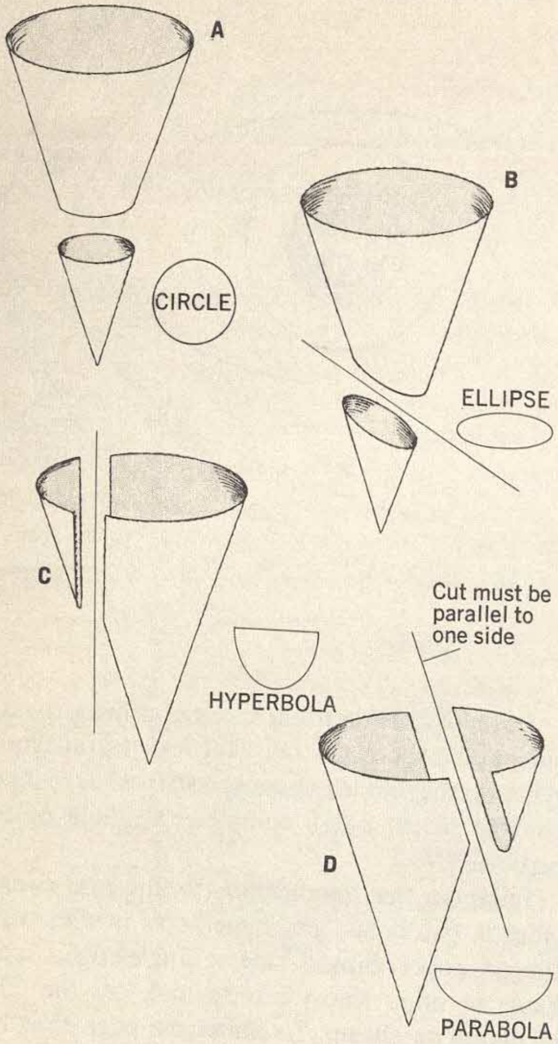
TYPES OF ORBITS

Have the children cut circles, ellipses, parabolas, and hyperbolas out of construction paper. What do they notice about the shapes? Is it really possible to cut out a complete parabola or hyperbola? *(No.)*

Point out that another way to illustrate circles, ellipses, parabolas, and hyperbolas is with cone-shaped paper cups. Using a single-edged razor blade or other sharp cutting tool, cut the cone in planes as shown. Examine the edge that has been cut. You may wish to dip this edge in dry tempera powder, ink, or on a rubber stamp pad and print the resulting shape on paper. Label the shapes correctly.

What is the difference between a hyperbola and a parabola? A circle and an ellipse? Help the children see that circles and ellipses are closed, while hyperbolas and parabolas are open.

Extending Ideas: Help the children see that the flight path that a spacecraft takes is dependent on its velocity and direction. At a speed less than orbital velocity, it will only fall back to Earth. If it achieves orbital velocity, it will travel around the Earth. If it exceeds orbital velocity, it will escape the Earth and go into deep space. What gives the spacecraft enough thrust to achieve the proper flight path? What effect does the satellite have on the size of the rocket? Discuss with the



children the relative sizes of the rockets needed to place a large, heavy satellite in orbit and a small spacecraft into a deep-space trajectory. How powerful does a rocket have to be to take three or more men to the moon? To Mars?

Learning: A spacecraft may follow any one of four flight paths—a circle, an ellipse, a hyperbola, or a parabola.

Summing Up Ideas: In this section, the children were introduced to the orbits and flight paths of spacecraft. They learned of the two factors influencing the orbit or flight path, the spacecraft's inertial tendency, and the gravitational forces acting upon it. They also learned of the four shapes that a flight path can take—a circle, an ellipse, a parabola, and a hyperbola.

HOW IS THE SPACECRAFT GUIDED AND CONTROLLED?

Lifting the launch vehicle off the Earth is only the beginning. It must achieve a precise speed to go into orbit around the Earth (over 17,500 miles per hour) or achieve escape velocity (25,000 miles per hour) to go into deep space to intercept or fly by the Sun, the Moon, or the other planets.

For a spacecraft to achieve the proper trajectory, a high degree of precision must be attained. It is not a simple task to intercept a relatively tiny body such as the Moon or a distant planet in the far reaches of space.

ACTIVITY 62 (x,y,z)

REACHING THE MOON

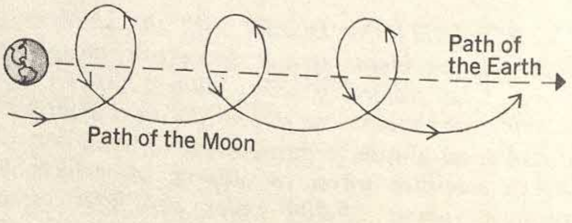
Purpose: To show how difficult it is to send a spacecraft from the Earth to another heavenly body

Concept to be developed: A high degree of precision is required in aiming a spacecraft at the Moon.

Materials needed:

Small ball
Long piece of wrapping paper
Protractor
Rulers
Yardstick

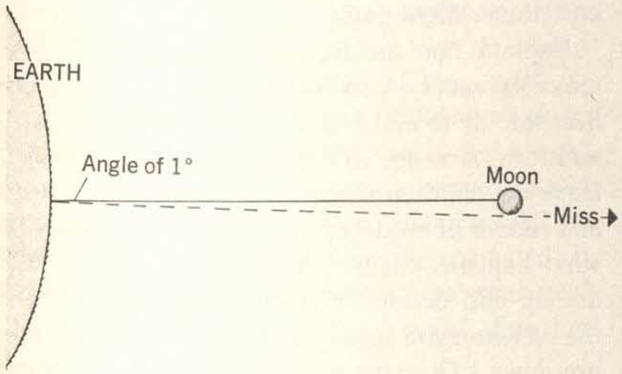
INTRODUCTION: The children can get some idea of how difficult it is to reach a fast-moving body in space. Draw a large circle on the playground. Have one child, representing the Moon, stand on the circle (the Moon's orbit). Let another child, representing the Earth, stand in the center, holding a small rubber ball. Ask the "Moon" to start moving quickly around the "Earth" as the "Earth" turns in the center of the circle. Have the "Earth" roll the ball to the "Moon" while they both are in motion. Did the ball (spacecraft) hit the "Moon?" How easy is it to roll a ball from one child to the other? (The children should experience some difficulty.)



Actually, both the "Moon" and the "Earth" should be racing across the playground at the same time to simulate their motion through space.

Emphasize that to intercept a point in space, accurate knowledge of speed and distance must be obtained. A small error in computation can cause the spacecraft to miss its destination by millions of miles.

On a large piece of paper, draw two lines at right angles. Place a circle on the horizontal line close to the edge of the paper to indicate the Moon. Using a protractor, measure an angle of 1° from the right angle. Extend a line through the 1° mark to the edge of the paper. This would be the path of the spacecraft if an error of only one degree was made. Measure the line's distance from the Moon. This indicates how the spacecraft would miss the Moon if such an error were made.



If each inch equaled one million miles, by how many miles would the spacecraft miss the Moon at one degree of error? The children should see that a slight error would cause a miss of a great many miles. The farther away the target, the greater the error would be.

Besides the need for accurate computation of the vehicle's trajectory, there are many other factors that can cause the vehicle to deviate from its flight path. The walls of the rocket are comparatively thin. When it is filled with many gallons of liquid fuel, it has a tendency to wobble and vibrate. The children can experience this sensation when they attempt to carry a large tub of water across the playground. Impact by meteors, winds in the atmosphere, the unequal pull of gravity at the various altitudes from the Earth, the gravitational attraction of other objects in space, small imperfections in fuels and mechanisms—all of these can cause the launch vehicle to vary from its desired path.

Extending Ideas: A major problem, then, is making the space vehicle go to its proper destination. This is accomplished by a complex system of *guidance* and *stabilization* that keeps the vehicle on its prescribed course. High-speed computers on the Earth and on board the spacecraft constantly check its speed, position, and direction. Information from the spacecraft is radioed (telemetered) to many *tracking stations* around the Earth.

Help the children locate the many United States tracking stations on a world map. These are the locations where information from space is collected. What countries cooperate in tracking spacecraft?

Signals from the tracking stations are radioed back to the spacecraft and activate the machinery to correct its speed and direction. When man is aboard the spacecraft he, too, can make corrections.

Learning: A great deal of precision is required to send a spacecraft from the Earth to any other heavenly body.

ACTIVITY 63 (x,y,z)

OBSERVING THE NEED FOR A GUIDANCE SYSTEM

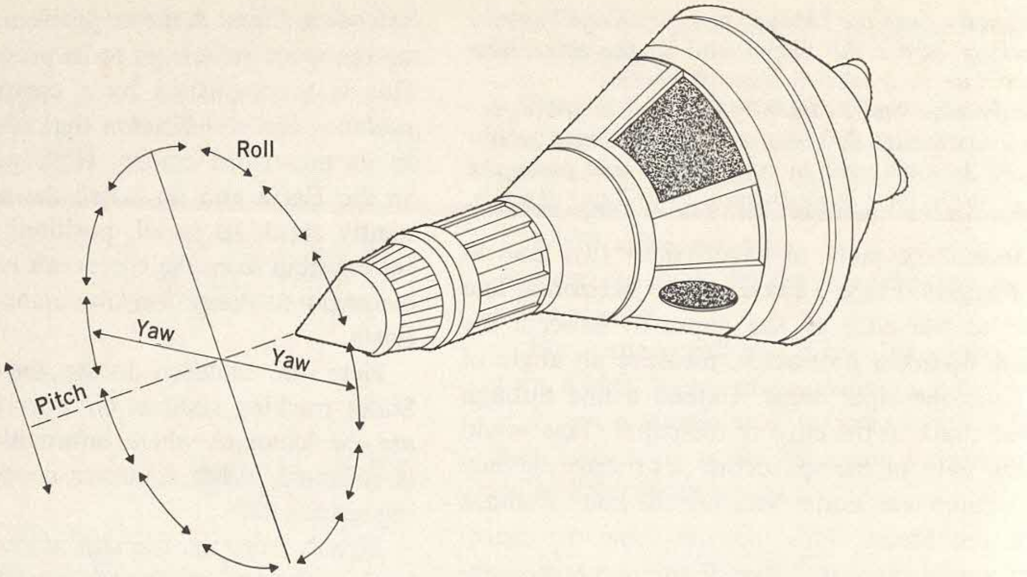
Purpose: To show why spacecraft require guidance systems

Concept to be developed: Guidance systems stabilize the flight path of a spacecraft.

Materials needed:

Balloon
Long, thick soda straw
Broom
Rubber band

INTRODUCTION: How can a spacecraft be stabilized so that it can be guided into its proper flight path? The children can get the "feel" of the need for stabilization *by attempting to balance a broom handle upright in the palm of one hand. They will observe that when the broom begins to tip one way, the hand must be moved so as to counteract the direction of fall. They should also notice that the hand must be so maneuvered in all directions: up and down, side to side, forward and backward. Just as the broom handle moves forward and backward and side to side, the spacecraft, too, has a tendency to move in these three ways while it is traveling forward. Can the children themselves move in three directions while they are walking forward? Have them try it and see.*

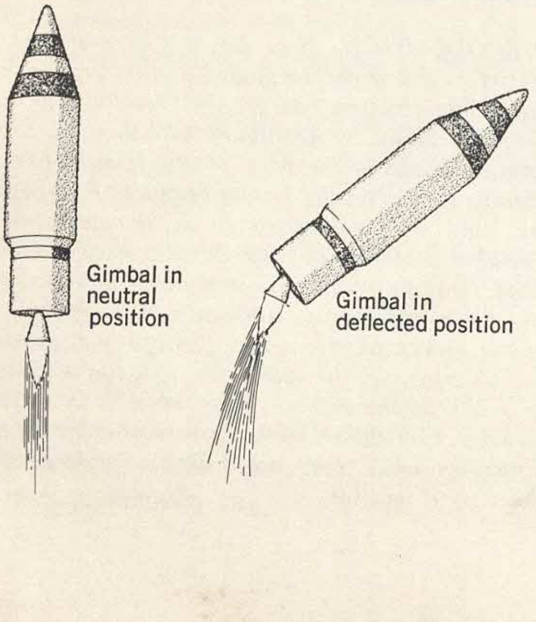


Have a child blow up a balloon and release it. Note the path it follows. It does not move in a straight line because it has no guidance system. To give the balloon a rudimentary guidance system, attach a long, thick soda straw to the nozzle of the balloon with a rubber band. Blow the balloon up and release it once again. Does it travel in a straighter path? *(It should, for the soda straw tends to stabilize it.)*

Introduce the following terms to the children for their study of stabilization.

Roll is a rotating motion. *Yaw* is a side-to-side motion. *Pitch* is an up-and-down motion.

Ask the children to theorize about ways in which they think the spacecraft can be stabilized so as to control these motions and be directed into proper flight paths.



Explain that an airplane is stabilized by the movable vanes in its wings and tail. These deflect the air to cause the airplane to climb, dive, and turn. Arrange to take the class to an airport. Have the children observe the elevators, ailerons, and rudder of model or actual airplanes. Describe what happens when elevators in the tail section are up and down. *(The airplane goes up when the elevators are up and down when the elevators are down.)* Describe what happens when a plane banks. In what position must the ailerons be to bank left? Right? *(Left aileron up, right aileron down, the plane banks to the right, and vice versa.)*

Since there is no air in space, would it be possible to use elevators and ailerons on rocket ships? *(No.)* Could the children devise a method to stabilize a rocket, using this same principle? Suggest that one way is to insert vanes or rings (gimbals) into the exhaust nozzle of the rocket to act as a rudder. The expanding gases that are escaping from the rocket can then be deflected in any direction.

The children may now have some understanding air coolers, and air conditioners. Many of these have wind deflectors in front of the fan that cause the air to be deflected in a certain direction.

Point out that these guidance systems are used during the *initial guidance,* while the rocket engines are still burning fuel. However, when no more gas is created to escape through the gimbals, how can the spacecraft be maneuvered?

After the engines have stopped firing *(burnout)*, the spacecraft is in free flight. It is falling around the Earth or coasting to another planet or to the Moon. What can be used to keep or send the spacecraft in its proper direction? Encourage the children to speculate and suggest ideas as to how this might be done. (It would be well to review the action–reaction principles in Activities 52 and 53.)

The children may now have some understanding that, to control the vehicle in space, a system of small corrective jets or rockets is employed. The amount of thrust needed for correction is small. Ask the children why they think this is so. *(Because the inertia of motion is balanced by the force of gravity, resulting in a state of* weightlessness. *There is no atmosphere to cause friction. There are no other forces to change direction. Therefore, it takes only a small force to change the direction of the spacecraft.)* These small jets might use hydrogen peroxide or nitrogen under pressure. When the direction must be altered, small thrusts are exerted in one direction, which moves the craft in the opposite direction. By this means roll, pitch, and yaw can be corrected. In addition, by the same process, the spacecraft may be turned over or in the opposite direction.

Learnings: In order to guide the spacecraft in a proper orbit, a guidance system must be employed. This may include gimbals in the engine. Small rocket engines are used to attain and maintain a proper orbit. They are also used to overcome pitch, roll, and yaw.

ACTIVITY 64 (x,y,z)

OBSERVING SPIN STABILIZATION

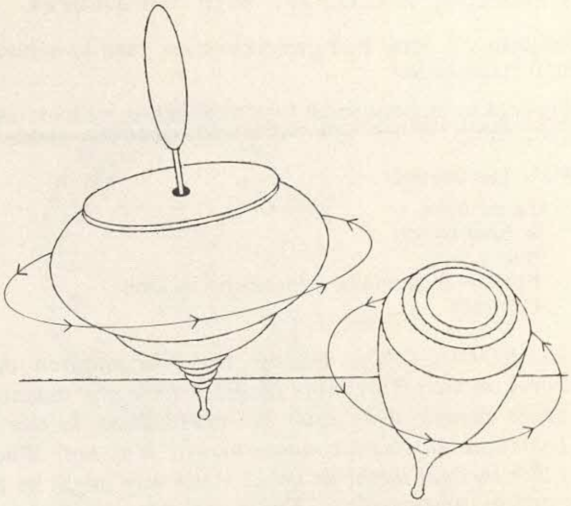
Purpose: To demonstrate another means of stabilizing a spacecraft

Concept to be developed: Spinning the spacecraft on its axis as it travels tends to stabilize its flight path.

Materials needed:

Piano stool or swivel chair
Bicycle wheel
Iron rod
Bicycle
Toy tops or other spinning toys

INTRODUCTION: Suggest to the children that they can discover another way to keep the spacecraft in a stabilized position. Spinning tends to stabilize the spacecraft on its course. Recall with the class the action–reaction principle. Point out that, likewise, spinning in one direction can counterbalance those forces in the opposite direction that cause the spacecraft to move off course.



A child can experience this stabilization effect through spinning by standing on a well-oiled piano stool or swivel chair and attempting to turn himself around. He may find that as he attempts to move in one direction, the stool or chair moves in the opposite direction.

Another way to experience this is by spinning a large wheel. Place an iron bar or rod through the hub of a bicycle wheel (or perhaps the axle could be extended) so that a child may hold the wheel in his hands. Have him spin the wheel while holding the handles. Seat a child on the piano stool or swivel chair. Have the child hold his feet off the floor and twist the spinning bicycle wheel sharply. What happens? *(It resists turning.)*

Encourage the children to manipulate and experiment with tops. Have them try balancing tops on strings and on the edges of tables.

Tops and other spinning toys can help the children understand spin stabilization. Ask them why tops remain upright while spinning but fall when they stop.

Can the children speculate as to why a space station will be made to spin? Can they guess why the Earth does not wobble much as it travels through space?

Learning: Spinning a spacecraft around its axis is another way of stabilizing its flight path.

ACTIVITY 65 (x,y,z)

STABILIZING SPACECRAFT WITH GYROSCOPES

Purpose: To show that gyroscopes are used to achieve spin stabilization

Concept to be developed: Inertial guidance systems use gyroscopes, for the spinning gyroscope is very stable.

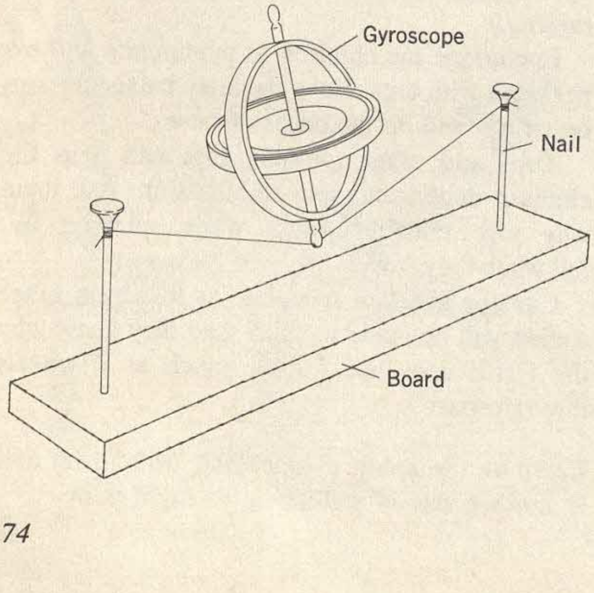
Materials needed:

Gyroscopes
Rubber bands
Heavy nails
Board, 10 inches by 4 inches by ½ inch
Hammer

INTRODUCTION: Discuss with the children the effect on man if an entire launch vehicle and manned space capsule were spun for stabilization. Is this a technique suitable for manned craft? Why not? What other method might be used? (One way might be to employ gyroscopes.) *Encourage the children to manipulate and experiment with gyroscopes. Have them try balancing gyroscopes on strings and on the edges of a table. Ask them to observe the motion. Why don't gyroscopes fall over while spinning?*

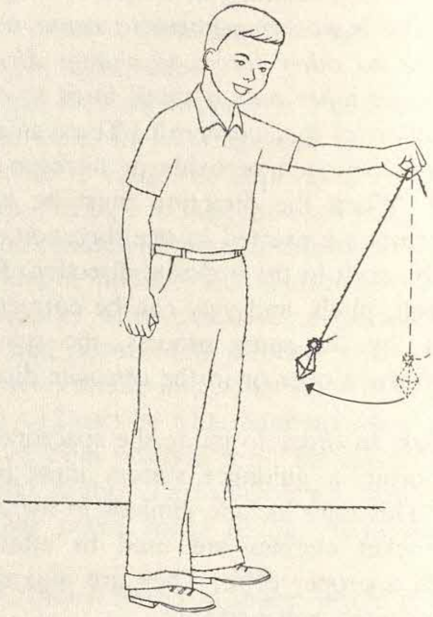
Construct a simple guidance system as follows: Hammer a large nail into each end of the board. Attach the rubber bands to each end of the gyroscope and around the nails. The gyroscope should be suspended freely. Then have a child spin the gyroscope.

While the gyroscope is spinning, have the child tilt the wooden base into various angles and positions. Let the children observe the motion of the gyroscope. What happens? *(A spinning gyroscope resists any force that acts to change the position of the gyroscope along its axis of rotation.)*



Since the spacecraft might move in any of three motions (roll, pitch, and yaw), how many gyroscopes would be needed to correct these movements? *(Three.)* Can the children decide how three gyroscopes might be mounted so that their axes of rotation would be in three different planes?

Learnings: A spinning gyroscope resists any force that acts to change the position of the gyroscope along its axis of rotation. For this reason, three gyroscopes can be used to stabilize the flight path of a spacecraft. One gyroscope must be used to correct the roll, the second to correct the pitch, and the third to correct the yaw.



ACTIVITY 66 (y,z)

CONSTRUCTING AN ACCELEROMETER

Purpose: To demonstrate how the speed of a spacecraft can be measured

Concept to be developed: An accelerometer is used to measure changes in the speed of a spacecraft.

Materials needed:

Weights
String
Paper
Roller skates or bicycle

INTRODUCTION: Explain to the children that besides stabilization for roll, pitch, and yaw, the launch vehicle must also achieve proper speed to go into deep space or to go into a proper orbit around the Earth. Ask them to think about how we can tell *how fast the launch vehicle is going, or if it is going too fast or too slow. Mention that aboard the vehicle there is a small device called an* accelerometer. *This uses the principle of inertia to measure a change in the launch vehicle's velocity in any direction. It is part of the* inertial guidance system. *It is very sensitive and measures the slight variations in the vehicle's speed forward and from side to side. If the launch vehicle's speed is too fast or too slow, the accelerometer sends this information to the guidance system. The guidance system includes* computers *that determine how much the speed should be corrected.*

The principle of an accelerometer can easily be seen by suspending a weight from a string. Have a child hold the string, allowing the weight to hang freely. When the string and weight come to rest, have the child thrust his hand forward and observe the motions of the weight.

Variations may be tried by placing the child holding the string on roller skates or on a bicycle. In each case, as the vehicle is moved faster or is started, the weight has a tendency to remain stationary. It will, therefore, appear to swing back. Have the children try moving it gently and rapidly. Notice how the weight tends to remain in the same location even when the string is moved.

By placing a calibrated card behind the string, the children can measure to what extent the weight is deflected. The faster it moves, the greater the deflection that will be noticed. The children may wish to build their own accelerometer. Perhaps they could mount such a device on the rocket-powered vehicles they constructed previously.

Extending Ideas: Can children explain how the spacecraft can be guided while it is in space, where there is no up, down, forward, or backward? Since the spacecraft will be an independent body in space, just like the Earth, its position among the stars and planets can be determined in the same way we on Earth have determined our position, direction, and speed. (Chapter 2 contains ideas regarding triangulation, parallax, and motion.) The spacecraft, too, can be equipped to sense, and fix on, the light from the stars, the Sun, the Moon, and the Earth as points in space from which measurements can be made. How quickly must calculations be made? How accurately must measurements be made? What kind of equipment might be used?

MARINER SPACE PROBE

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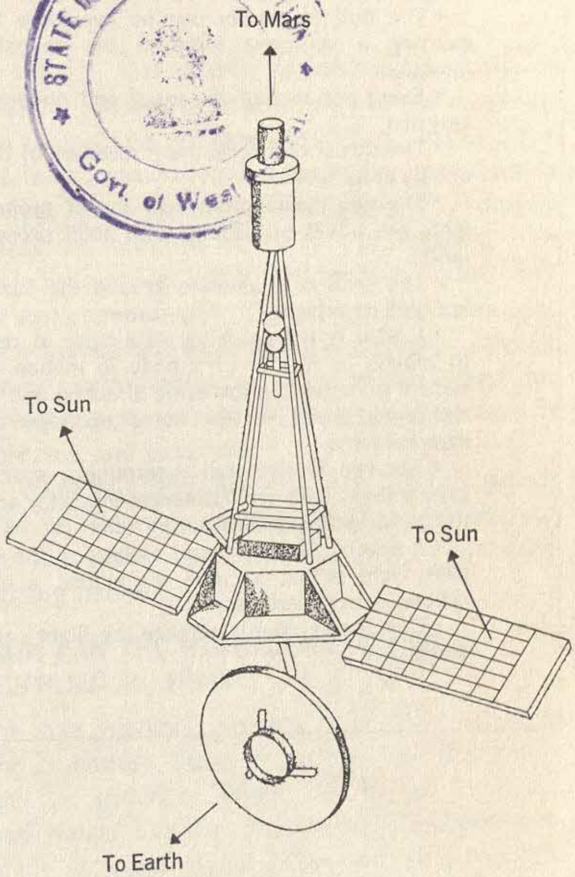

Learning: An accelerometer measures deviations in the speed of a spacecraft.

Summing Up Ideas: In this section, the children were introduced to the need for, and means of, controlling spacecraft. They learned that the utmost precision is required to reach another celestial body from the Earth. They learned of the guidance systems used to correct the deviations from the flight path caused by roll, pitch, and yaw. They saw how an accelerometer can be used to detect changes in the spacecraft's speed. In addition, they learned of the radio communication system by which we maintain contact with spacecraft.

IMPORTANT IDEAS IN THIS CHAPTER

For the kindergarten, primary, and intermediate grade children, the ideas with the most meaning and application are:

- The Earth's gravitational attraction pulls things toward the center of the planet.
- The pull of gravity can be overcome by exerting a sufficient force in the opposite direction.
- Every action has an equal and opposite reaction.
- The thrust of a rocket is a measure of the energy of its fuel.
- The two primary types of rocket propellants are liquid propellants and solid propellants.
- The path of a satellite around the Earth is called its orbit.
- Inertia is the tendency of a body at rest to remain at rest or of a body in motion to remain in motion, in the same direction and at the same speed, unless acted upon by an external force.
- The two factors that determine a spacecraft's flight path are its inertial tendency and the gravitational forces acting upon it.
- A spacecraft may travel along any one of four flight paths: a circle, an ellipse, a parabola, or a hyperbola.
- Guidance systems stabilize the flight path of a spacecraft.
- Spinning a spacecraft around its axis is one way of stabilizing its flight path.
- Three gyroscopes—one along its roll axis, one along its pitch axis, and the third along its yaw axis—can be used to stabilize a spacecraft's flight path.

In the intermediate and upper grades, the children should be led to develop concepts that are more complex and quantitative:

- A great deal of energy is required to overcome gravity completely.
- An engine that burns a fuel in oxygen must carry its own oxygen into space with it.
- The energy of an expanding gas can cause a vehicle to move; this movement can be explained by the principle of action–reaction.
- Specific impulse is a measure of the amount of thrust a propellant will produce per unit time.
- The mass ratio of a rocket is its weight before launching divided by its weight after all its fuel has been burned; the greater a rocket's mass ratio, the greater will be its final speed.
- Rockets are designed to reduce air resistance and the frictional forces they encounter in the atmosphere.
- A spinning gyroscope resists any force that acts to change its position along its axis of rotation.

5

INVESTIGATING HOW MAN CAN EXIST IN SPACE

Of all the aspects of space exploration, children seem most interested in man himself:

"How can an astronaut eat when he is weightless?"

"Why do men have to wear space suits on the Moon?"

"How can man return from space?"

"How is a spacecraft slowed down?"

"What has man discovered about space?"

Man in space is like a fish out of water. He has been taken out of his natural habitat. The principles of ecology tell us that a living organism cannot exist long in a foreign environment. The organism must, therefore, either accommodate itself to the new environment, take part of the old environment along with it, or die.

Man has faced danger before. The quest for knowledge, the spirit of adventure, and the challenge of accomplishment motivated Columbus, Magellan, the Wright brothers, Lindbergh, Gagarin, Glenn, Tereshkova, and others.

With adequate protection, the necessities for survival, proper transportation, and adequate communication, man will venture into space and return. To accomplish this, he must first know more about how life functions in an Earth environment. He must know what the conditions are in space, and he must solve some of the problems of accommodating himself to a foreign environment. This chapter investigates the conditions necessary for life, explores the environment of space, and examines some ways man might exist under these conditions.

Once man is in space, another large problem looms before him: safe return. Entering the Earth's atmosphere, passing through the barrier of air, and landing safely pose many problems for man. This chapter also deals with the problems of returning from space. What will happen if man misses the Earth? How can the spacecraft be guided correctly? Where will the spacecraft land?

Finally, this chapter is intended to help the children understand the impact of the space age on society. As we examine history, we find that each age has brought man higher standards of living, new products, and stronger economy. Since the inception of the air age, man has been able to transport goods, and to travel, more swiftly and economically. The air age has introduced new metals and fuels and has increased international communication. The nuclear age has brought new sources of energy, combatants of diseases, and industries.

What will the space age bring? It has already had its effects on national health, new products in the home and industry, and cooperation among nations.

HOW CAN THE NECESSITIES OF LIFE BE SUPPLIED IN SPACE?

As man ventures into space, he must ascertain the conditions there: What are the temperature and the pressure? Where can he get food, air, and water? Can the human body function normally in space? What effect will *weightlessness* have? Can man withstand high *G-forces* at blast-off? Will he be affected by meteors and radiation? Is there other life in the universe?

Refer to Chapter 2 to help the children review and determine what space is and what conditions exist there. Is there air in space? Space is not entirely empty. There are a few thousand molecules of gas in every cubic foot. Is there enough for man to breathe?

Besides a few molecules of very light gases, there are meteors that travel at speeds over 25,000 miles per hour and various cosmic rays and particles of radiation from the Sun. (Refer to Chapter 3.)

There will be no weight in space. Recall with the children that man has weight because he is attracted toward the center of the Earth. Man and his space capsule will be in a state of weightlessness. The inertia of motion is balanced by the pull of Earth's gravity. This results in an equalization of forces that produces weightlessness. (Refer to Chapter 4.) How will man react to this condition?

ACTIVITY 67 (x,y,z)

OBSERVING THE EFFECTS OF AIR PRESSURE*

Purpose: To demonstrate that air pressure inside a space suit or space capsule must be regulated for man to survive

Concept to be developed: Man can survive in space only if he has an atmosphere similar to that on earth.

Materials needed:

- Glass of water
- Heavy cardboard
- 1-gallon can with a tight-fitting lid
- Water (½ cup)
- Hot plate
- Bottle of carbonated beverage
- Tight-fitting cork or stopper
- Pyrex nursing bottle
- Balloon
- Rubber band
- Pan of water

INTRODUCTION: Man lives at the bottom of the atmosphere. The molecules of gas in the atmosphere, just as is true of any other matter, have weight. These, too, are being drawn to the Earth by gravity. The atmosphere is pressing down on objects on the Earth's surface. Can we feel this pressure? Can we notice the effects of pressure? Help the children develop an understanding of air pressure by using, examining, and constructing barometers and participating in activities involving air pressure.

How much pressure is being exerted on the Earth? Have the children find out the normal pressure of air at sea level. *(About 14.7 pounds per square inch.)* This means that the weight of a column of air one inch square and extending upward to the edge of space would be about 14.7 pounds. How many pounds per square foot is this? *(2,116 pounds per square foot.)* As we go to higher altitudes, does the amount of air in the column above us decrease? *(Yes.)* What effect would this have on pressure? *(It would decrease.)*

If there is 14.7 pounds of pressure against each inch of our bodies, can the children calculate the total amount of pressure over our entire body surface? The children can soon realize that there are many tons of air pressing on our body surfaces at all times. Why are our bodies not crushed under this tremendous weight? *(There is an equal pressure of air inside our bodies that is pushing out.)* We exist in a narrow zone on Earth where pressure is such that man's bodily functions can be carried on. What happens when this balance in pressure is upset? *(Man dies.)*

To observe the effects of high pressure, have the children pour some water in the can to a depth of about ½ inch and heat it to boiling. Allow the water to boil a few minutes to remove the air inside the can. Then cap the can tightly and remove it from the hot plate. Observe what happens when it cools. To speed up the cooling process, the can may be placed under cool water. *(The walls of the can should cave in.)* Why? *(The air pressure outside the can is greater than the air pressure inside the can.)* How was the air pressure inside the can changed?

To observe the effects of low pressure, open a bottle of a carbonated soft drink. Let the children notice what happens as soon as the lid is removed. Why do bubbles rise? Why are there no bubbles visible when the lid is kept on? Recap the bottle with an airtight stopper. What happens to the bubbles? *(A gas has been dissolved inside the drink. When the drink is kept under pressure, the gas remains dissolved. When the pressure is removed, the gas turns to vapor and boils, or bubbles away.)*

Point out that there is gas in man's body; it is in the form of oxygen, nitrogen, and carbon dioxide in our joints, lungs, stomach, cells, blood, and intestines.

Now apply this situation to man in space by asking: What would happen to man if he ventured outside his zone of comfortable pressure? How high can man climb without feeling the effects of low pressure? How deep in the ocean can man descend without taking along protection from too much pressure? What are the "bends"? Some children may have experienced high pressure when they tried to swim deep in a lake or pool. Some may have felt their ears "pop" when they drove high in the mountains. Why must airplanes be pressurized to keep passengers comfortable? What would happen if the pressure

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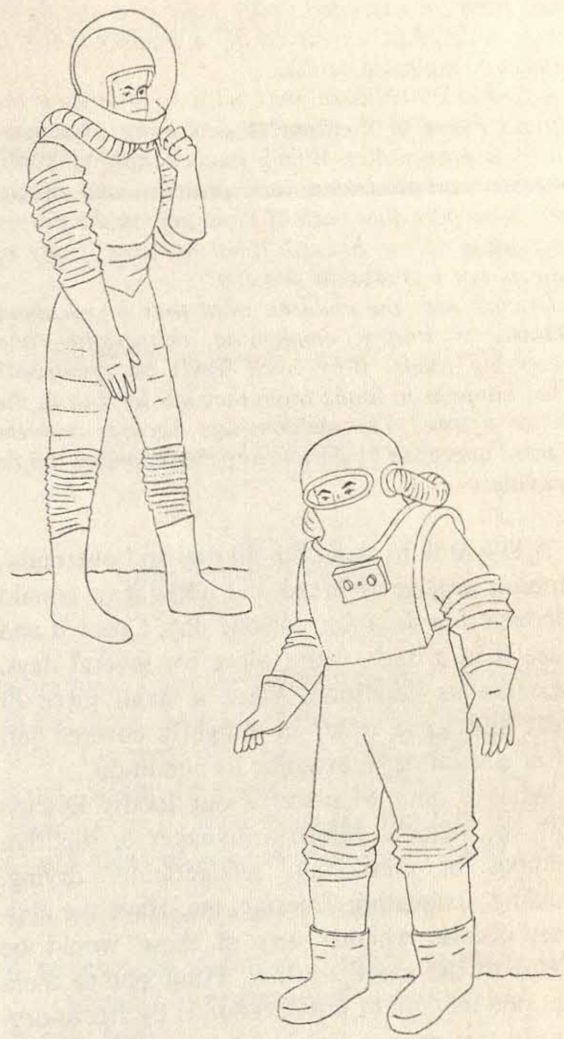
*For a more thorough explanation of air pressure and Activities to demonstrate it, see *The Earth,* by Lawrence Hubbell (Investigating Science with Children Series; Darien, Conn., Teachers Publishing Corporation, 1964).

outside our bodies were removed, as it would be in space?

Close the neck of the balloon so that the air pressure inside the balloon equals the air pressure outside. (Do not blow it up; just blow it so the walls stand out.) Tie it with a rubber band. Put about ½ cup of water in the baby bottle and place it in a pan of boiling water. Place the pan on the stove and heat until the water inside the baby bottle begins to boil. When the water is boiling fast, drop the balloon into the bottle and cap the bottle tightly. Remove it from the pan and hold it under a stream of cool water. What happens to the balloon inside the bottle? *(It expands.)* What has happened to the pressure inside the bottle? *(The pressure inside the bottle has decreased, and the air inside the balloon has expanded to equalize the pressure.)*

What would happen to man in space if there were no protection from lack of pressure? From these Activities (and others), the children may predict that the gas inside his body would expand so that he might blow up. The gas that is dissolved in his body would soon come out of solution and escape ("bends"). His body fluids would boil. Therefore, the question becomes: How can man be protected from lack of pressure? The children may wish to speculate as to how this might be done: capsules, space suits, etc.

Extending Ideas: The children will be aware by now that, in any case, man must take with him some device to maintain or exert nearly normal pressure on his body. For high-altitude space travel, space suits of a soft fabric may be used; the walls of these suits can contain expandable air pockets so that pressure can be exerted against the space traveler's body. However, for deep-space or lunar exploration, this soft material might not be adequate protection against the dangers of radiation and speeding meteorites. Actually, the space suit might resemble a small spaceship: constructed of rigid material, air-conditioned, pressurized, and supplied with oxygen. The children may enjoy discussing such questions as the following: What are the disadvantages of so clumsy a suit? How will man move, pick up things, and work in such a suit? Have the children collect pictures of various types of space suits to aid in their discussion. They may wish to design suits according to their own specifications.



Learnings: Man requires an air pressure of about 15 pounds per square inch in order to survive. To maintain this pressure in space, man must wear a pressurized space suit or remain in a pressurized capsule.

ACTIVITY 68 (x,y,z)

SEEING THE NEED TO PRESERVE FOOD

Purpose: To show that the food man takes into space must be specially treated

Concept to be developed: If man were to take untreated food into space, it would spoil before he had the opportunity to eat it.

Materials needed:

Various foods, including meat, bread, and milk
Jars
Dishes

INTRODUCTION: Raise such questions as: how can man's requirement for food and water be satisfied in space? Explain that a major problem *facing man on extended space trips is a supply of proper food. Just as on earth, a balanced diet is required to maintain health.*

A group of children may wish to interview the school's nurse or dietitian to determine what constitutes a proper diet. Which foods supply vitamins, minerals, carbohydrates, fats, proteins, and roughage? What part does each of these play in the proper functioning of our bodies? What happens if any of these is not included in the diet?

Discuss with the children what they know about methods of storing, condensing, dehydrating, and preserving foods. Why must foods be preserved? What happens to foods when they are left out in the air for a time? The children can discover answers to these questions by performing the following simple Activities.

Allow milk to stand out all day and overnight. Moisten a piece of bread and allow it to remain uncovered in the room for one day. Cover it and place it in a dark, warm place for several days. Examine its condition. Place a small piece of meat and some water in a tightly covered jar. After several days, examine its condition.

What is done to preserve our foods? Discuss with the school's cafeteria manager or dietitian methods of preserving: refrigeration, drying, pickling, irradiating, freezing, etc. Have the children discuss whether any of these would be useful to the space traveler. Point out to them that one method of preservation is by freeze-drying. In this process, foods are frozen and the ice crystals are removed by sublimation; that is, they pass directly from the solid to the gaseous state, without passing through the liquid state. This greatly reduces the weight, and the flavor is not altered noticeably.

Have the children examine the contents of various dietary supplements that doctors recommend for reducing or gaining weight. How are they packaged? Do they constitute a total diet? Some children may visit a food market to look for dehydrated foods and make a list of them. Can a balanced diet be planned by using only dehydrated foods?

Extending Ideas: The children may wish to apply their findings in devising a simple meal for the space traveler. How much food would be consumed by a man in one day? How long can man go without food? How much will this food weigh? How will it be stored and eaten?

Have a group of children weigh the food they eat in one meal; in one day. If it takes 516 days for a round trip to Mars, how much might the food weigh for a crew of three men? How big would the space capsule and the rocket have to be to accommodate this much food? Can the children devise some ways of reducing the bulk and weight of the food?

How can foods be packaged for space travel? Let the children examine various containers for foods. Consider and discuss these problems: Would the containers we use be useful in space? Have the children examine cans, milk cartons, plastic squeeze bottles, glassware, etc. Would any of these be suitable to take into space? How would they be disposed of when emptied? Can the children devise disposable or edible containers for foods (for example, sausage casings, sugar packing around candies, and edible fruit skins)?

The children may wish to inquire further into the problem of preparing foods. Have them discuss such problems as these: How can food be prepared in space? Can it be heated or cooked? How can it be removed from its package during weightlessness? Can it be shaken out? How can small bits and pieces be handled by a man in a space suit? How can liquids be poured? Have the children examine squeeze bottles and pipettes for transferring liquids.

Learnings: Man must take his food with him into space. The food must be preserved to keep it from spoiling.

ACTIVITY 69 (x,y,z)

SUPPLYING OXYGEN AND FOOD IN A CLOSED SYSTEM

Purpose: To show that a spacecraft can be made into a closed system

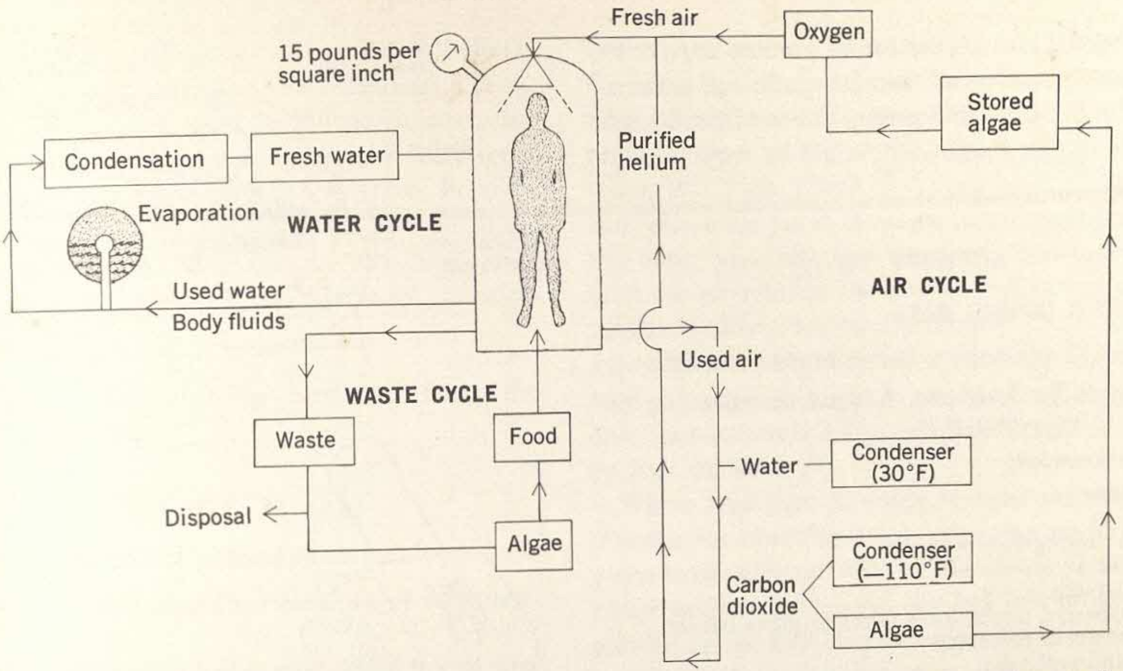
Concept to be developed: A manned spacecraft must be made self-sustaining.

Materials needed:

- Aquarium
- Fish
- Water plants
- Jar

INTRODUCTION: Ask the children what they think a closed environmental system might be, and list their ideas. Some scientists have been working with the idea of placing man inside a closed environmental

LIFE SUPPORT SYSTEM

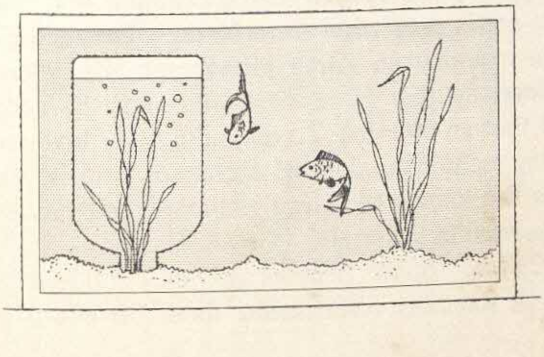


system in the spacecraft. They are experimenting with the idea of using plants for food and oxygen supply; man would contribute carbon dioxide and other necessities for plant growth. Some children may wish to design and experiment with such a system. They can do so in the following way.

Fill a jar with aquarium water and invert it in the aquarium over the water plants. Place the aquarium in the sunlight and have the children observe any bubbles that may rise in the jar. What are they? *(Oxygen.)* Where do they come from? *(Plants.)*

One type of plant that may be feasible to use for food in space is the *algae*. These green plants sometimes grow inside the aquarium and are found growing in ponds.

Grow some algae in the classroom. Place the aquarium in the sun. (An aerator that circulates air and water through the tank improves conditions for growth.) After several days, have the children observe the green algae growing in the aquarium. Can the children notice an increase in the green material as the algae grow and multiply? Let them observe the algae under a microscope if one is available. Do the fish eat the algae? *(Yes.)* Could man eat the algae? *(Yes.)* Could algae be used as a source of food? *(Yes.)*



Here is a recipe for algae cookies:*

4 tablespoons chlorella (algae) powder (obtainable from biological supply houses)
2 cups flour
½ tablespoon salt
3 tablespoons baking powder
4 tablespoons shortening
¾ cup milk

Cream shortening. Add sifted dry ingredients and milk. Roll out in ½-inch thick sheets. Spread with mixture of sugar, cinnamon, and butter. Roll up, slice into pinwheels, and bake at 350° for 10–15 minutes. The children may wish to devise other recipes.

Extending Ideas: Can man live on algae alone? Can algae supply air? How would algae be supplied with nutrients for growth? There are many problems related to meeting man's needs for food, air, and water in space. Help the children see that man must take these elements with him or become part of the system that produces them.

**Projects: Space*, by Judith Viorst (New York: Washington Square Press, Inc., 1962), p. 159.

Learnings: Through the use of green plants, such as algae, a spacecraft can be made self-sustaining. The plants would use up carbon dioxide and provide oxygen, and water could be recycled and distilled.

ACTIVITY 70 (z)

DETECTING COSMIC RAYS

Purpose: To construct a device to detect radiation

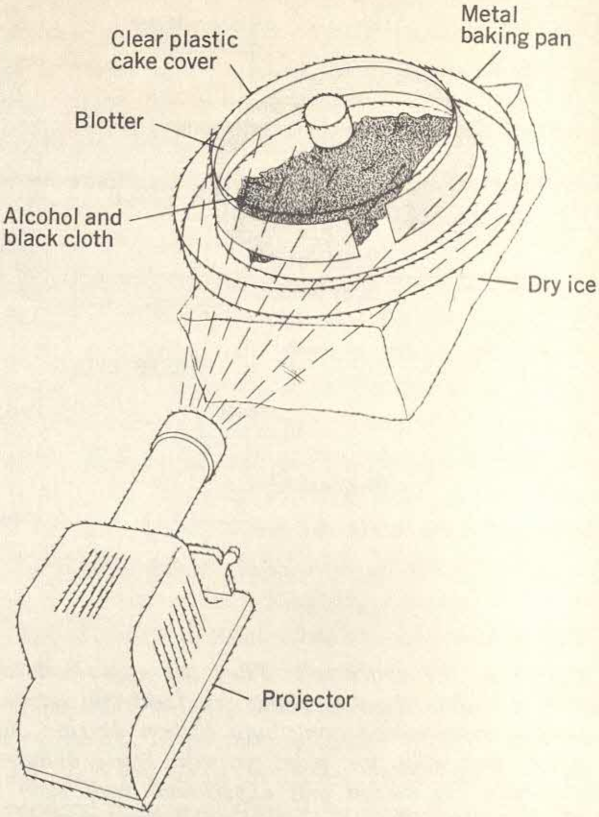
Concept to be developed: A cloud chamber may be used to detect cosmic rays.

Materials needed:

- Dry ice
- Alcohol
- Metal baking dish or pie tin
- Blotter
- Black cloth
- Transparent plastic cake cover or glass beaker
- Flashlight or projector
- Radium watch dial
- Strips of various metals

INTRODUCTION: Besides infrared (heat) radiation, recall with the children what other forms of radiation come from the Sun. Review X rays and ultraviolet radiation. (See Chapter 3.) What effect do these have on human bodies? How are we protected from them on Earth? How can man be protected in space? The following Activity will give the children some answers to these questions.

A simple cloud chamber may be constructed to detect the presence of cosmic rays. Cut a round piece of black cloth to fit the bottom of the baking dish. Pour some alcohol in the baking dish until the cloth is more than soaked. Cut the blotter into a long, wide strip so that it lines the inside of the plastic cake cover. Leave about a 1-inch opening in the blotter so that it does not completely line the cover. Place the baking dish with the alcohol directly on the dry ice. Place the cover over the baking dish, with the blotter standing in the alcohol. Darken the room and shine the projector or flashlight through the slit in the blotter. Soon, as the alcohol is absorbed by the blotter, a cloud will form inside the cake cover. Have the children look down through the top of the plastic cake cover, through the beam of light passing through the cloud. Careful observation may reveal white streaks, 2 or more inches long, in the cloud. What are these? (*Cosmic ray trails.*) Where do they come from? *(They are the trails of condensation left when a cosmic ray passes through the cloud. Cosmic rays come from space all the time.)* How do they pass through the walls of the classroom? If they can pass through the walls of the classroom, can they pass through a human being? What effect might this have on us?



Hold a watch dial painted with radium close to the cloud chamber. Do the children notice an increase in the number of white streaks? What causes this? (*Radiation from the radium.*) Place strips of various metals between the watch dial and the cloud chamber. Does this decrease the number of white streaks? Place various substances and materials between the watch dial and the cloud chamber. Which seem to stop the cosmic rays the best? Encourage the children to speculate as to how man might be protected from cosmic rays in space. *(This is called shielding.)*

Develop the Activity by explaining that man also needs protection from X rays. Let the children examine an X-ray photograph. Help them understand that X rays pass through the body, and that an overdose destroys the flesh. Invite an X-ray technician, dentist, doctor, or nurse to discuss the effects of X-ray radiation and precautions used in hospitals.

Extending Ideas: Encourage the children to search for more information about the effects of radiation. They will discover that the total effects are still largely unknown. Radiation is known to kill cells and is used in killing cancer cells. Research is being conducted to determine how much radiation man can tolerate. Possibly some chemicals could be injected into the body to make it resist radiation. In any case, man must be protected from the effects of radiation in space.

Learning: Man must be protected from the radiation in space.

ACTIVITY 71 (y,z)

DISCOVERING WEIGHTLESSNESS

Purpose: To demonstrate the condition of weightlessness

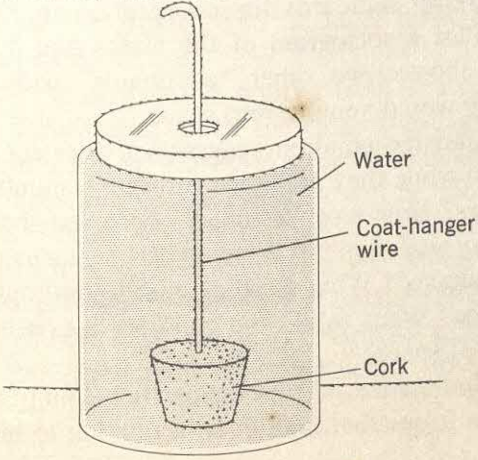
Concept to be developed: Man must devise special ways to cope with his weightlessness and that of other things when he is in space.

Materials needed:

1-quart fruit jar
Cork
Coat-hanger wire
Water

INTRODUCTION: Discuss with the children the effects of weightlessness. Perhaps they have experienced weightlessness momentarily on Earth, while diving from a diving board, swinging on a swing, riding in an elevator, or flying in an airplane. Discuss how it feels at the "top" of the dive off a diving board, at the peak of a swing, when an elevator drops rapidly, or when an airplane dips rapidly. The following Activity will reveal more useful information about weightlessness.

Suggest that the children make a bottle in which a submerged cork will not float. Have them take a quart fruit jar, bore a small hole in its metal cover, and fasten a cork to a piece of coat-hanger wire so that the cork can be held at the bottom of the water in the jar. If the wire is released while the jar is on the table, the cork promptly rises to the top; it is buoyed up by the water. But if you climb to the top of a tall ladder and release the jar at the same instant you release the cork, you will find the cork does not rise until the jar reaches the bottom, where someone catches it. The cork then promptly comes to the top. (Be sure that all safety precautions have been discussed. It might be wise to let the jar fall onto an outstretched blanket, held at the corners by four children.)*



When does man in space become weightless? *(During the coasting stage, after the rocket engines have stopped.)* Why? *(The space vehicle is either sufficiently beyond the pull of the Earth's gravity, or the Earth's gravity is counterbalanced by the rocket's forward thrust. Therefore, the spacecraft and everything in it are weightless.)*

How does the weightlessness affect man? Ask the children if they have ever dreamed they were falling. How did they feel? Ask the children to think about what would happen if the man in a spacecraft were to push against the wall, jump, or raise his hands during the weightless state. Will man expend as much energy during weightlessness?

Other questions that children might like to consider are: How would man eat or drink during weightlessness? What would happen to the circulation of the blood? What would happen to the carbon dioxide that man exhales during weightlessness? How could food be prepared? How would man sleep? Man himself must venture into space to try to find the answers to some of these questions.

Learnings: Weightlessness occurs when the spacecraft is either beyond the pull of the Earth's gravity or when the Earth's gravity is counterbalanced by the rocket's forward thrust. Man must be prepared to cope with weightlessness when he ventures into space.

ACTIVITY 72 (x,y,z)

CREATING G–FORCES

Purpose: To illustrate the tremendous forces an astronaut must withstand when the rocket is under power

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**Elementary School Science Bulletin,* October, 1962.

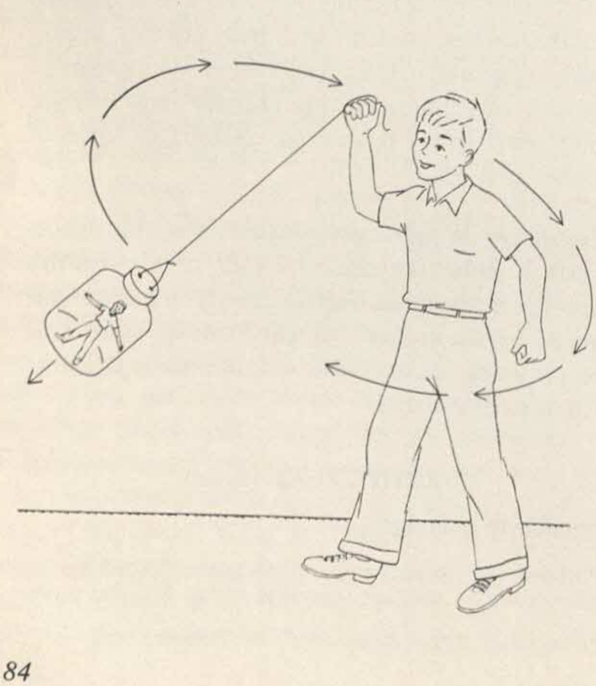
Concept to be developed: G–forces are caused when an object is accelerated.

Materials needed:

String or wire
Small doll
1-quart jar with a tight-fitting lid

INTRODUCTION: Encourage the children to speculate as to how man might move in a space station without floating. Could magnetic shoes be used? What effect would rotating the space station have? One way might be to create G-*forces. Make sure the children understand the definition of* G-*forces.* G-*forces are those forces that act upon a man's body exactly as gravitational forces would. The children can understand how* G-*forces are formed through the following Activity.*

Have a child place the small doll in a jar. Punch two holes in the lid of the jar and thread and tie a wire or heavy string through it. Have the child screw the cap tightly on the jar and whirl it around his head. Let the class observe what happens to the doll inside the jar. Is the doll forced to the bottom of the jar? *(Yes.)* Why? *(Because of inertia.)* Explain to the children that, as man leaves the Earth, the forces of the rocket motors must be great enough to take the rocket to its destination. This terrific acceleration acts to cause tremendous pressures (*G*-forces) on the astronaut. (Under a force of 1*G*, a man's weight is normal; with a force of 2*G*'s, his weight is twice normal; with a force of 3*G*'s, his weight is three times normal; etc.) The children have experienced an increase in *G*-forces when they have felt the thrust backward as a car or plane accelerates rapidly. During a launch, the astronaut will experience about 3.5*G*'s. Man has withstood up to 45*G*'s for brief moments in specially designed equipment. One way to overcome *G*-forces is to have the astronaut lie down so that the *G*-forces will be more evenly distributed over his body.



Discuss with the children how a chair might be designed to be comfortable for space travel. Of what should it be made? What position should it be in? How big should it be?

Extending Ideas: Bring to the children's attention the following problem: how will man react to the conditions of extended space flight? A spaceman can withstand *G*-forces, the vibration of the launch vehicle during take-off, weightlessness, confinement, and special foods for given periods of time. But how will he react to isolation for extended periods? Will he be able to live with fear?

Discuss with the children how they would feel if they were shut in a small, dark place for an extended period of time. Discuss their reaction if they have ever been lost. How would they feel if they knew they were constantly being observed with a camera, and many thousands of people were watching?

What are the qualifications for being an astronaut? One group of children might do research into the lives of the astronauts. What are their qualities? What common types of experiences have they had? What are some of their significant home, school, and career experiences?

How should teams be chosen to explore space? What should their qualities and competencies be? Develop standards for cooperation in space.

Plot a sociogram of the class. Ask the class to choose two other "astronauts" with whom they would venture into space.

Can the children suggest activities for spacemen while they are alone for weeks, months, and years? How have astronauts occupied their time in orbital flights? What experiments have they conducted? What did they wish to find out about space? What would the children like to find out about space?

Summarize this discussion by helping the children to see that man lives in relation to his environment. On Earth we take from and give to the environment. Thus, life processes are accomplished and maintained. When man ventures away from his natural home, the factors on which he is dependent must be supplied, and he must be protected from hazards. Thus, in order to understand man's necessities in space, we must understand man on Earth. To supply him and protect him is one of the major challenges of the space age.

Learning: Man must cope with *G*-forces, weightlessness, and other abnormal conditions when venturing into space.

Summing Up Ideas: In this section, the children were introduced to the factors that influence man's existence in space. They learned of his necessities, the things he must take into space with him. They learned of his need for oxygen, for adequate air pressure, for protection from extremes of temperature, and for protection from radiation. They learned how a spacecraft can be made into a self-sustaining system. In addition, they learned about the weightlessness man must learn to cope with in space and of the *G*-forces he must withstand while traveling into space.

HOW CAN MAN RETURN FROM SPACE?

Boosting a vehicle into space is a complex problem. Designing the equipment, achieving the proper orbit, and supplying the necessities for life are complex problems. But the return from space is also filled with complexities. Many of the same factors that plague man's leaving Earth hinder his return. He must combat the friction of the atmosphere; he must counteract the Earth's pull of gravity; and he must resist tremendous speed.

As the space capsule returns from space, it will be traveling at much the same speed as it was when it left the Earth. If it has been in orbit in an ellipse around the Earth, it will be traveling at an orbital velocity of about 17,500 miles per hour. If it is returning from the Moon or deep space, it will be traveling at escape velocity (about 25,000 miles per hour). Gravity will be the factor that pulls the spacecraft toward Earth.

ACTIVITY 73 (y,z)

OBSERVING THE ACCELERATION OF FALLING OBJECTS*

Purpose: To demonstrate the acceleration of a freely falling object

Concept to be developed: A freely falling object accelerates at the rate of 32 feet per second every second.

Materials needed:

5 spools
15 feet of narrow ribbon
Stepladder or high table

INTRODUCTION: As the spacecraft travels through the vacuum of space, there is relatively little to slow or hinder its speed. Discuss with the children the effects of tremendous speed on various objects. Discuss the effect of great speed in automobile accidents. Have the children recall their experiences in attempting to stop when riding their bicycles at great speed. What methods, equipment, and techniques do airplanes use to reduce speed? (Spoilers, reversing propellers, reverse jet thrust, flaps, etc.)

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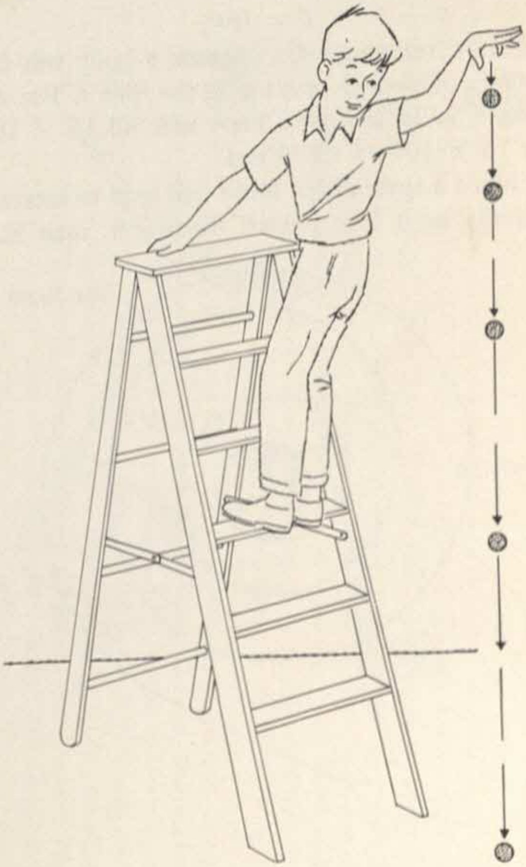
*For a more thorough discussion of acceleration and other Activities with which to demonstrate it, see *Motion*, by Lois Dunn (Investigating Science with Children Series; Darien, Conn., Teachers Publishing Corporation, 1964).



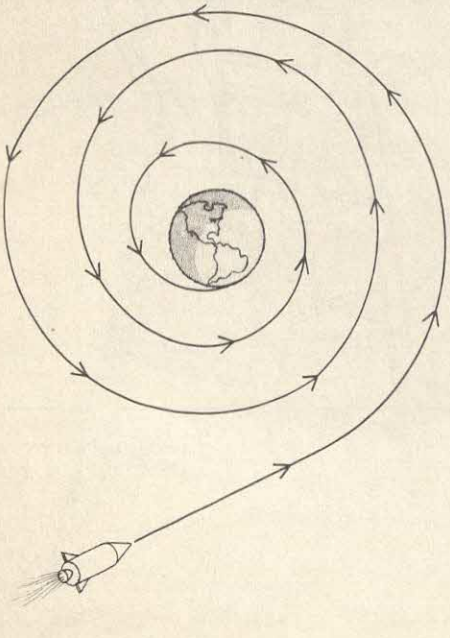
Have a child thread the ribbon through the spools and tie the spools at unequal, measured intervals—1 foot, 3 feet, 5 feet, 10 feet, and at the end. Have him stand on a stepladder, chair, or table and hold the ribbon so that it hangs straight down. Ask him to release the ribbon and have the class listen closely for the "clicks" as the spools reach the floor. Did all the spools "click" at the same time? *(No.)* Did they "click" at regular intervals although the spools were spaced unequally? *(Almost.)* Did they "click" with inequality similar to their spacing? *(No.)* The children should observe that although the spools are not evenly spaced, the "clicks" are almost evenly spaced. The spool that fell the greatest distance increased its speed as it fell so that it "caught up" somewhat with the other spools.

Explain to the children that the rate of acceleration is 32 feet per second each second, and that this means that the longer a body continues to fall, the greater its speed will become. To find the distance a body will fall in a given amount of time, some children might like to work with the equation

$$d = 16t^2,$$

where d represents the distance a body will fall from a stationary position in the time t. For example, in 10 seconds a body will fall 16×10^2, or $16 \times 100 = 1{,}600$ feet.

Since a spacecraft's speed will tend to increase rapidly as it falls toward the Earth, man may wish to have it return to the Earth in a spiral trajectory, such as the one shown in the illustration. In this way, instead of falling freely and accelerating very rapidly, the spacecraft's descent will be slowed somewhat by air resistance and frictional forces.



Learnings: A freely falling body accelerates to great speeds quite rapidly. A body in free fall accelerates at the rate of 32 feet per second each second.

ACTIVITY 74 (x,y,z)

INCREASING TEMPERATURE BY FRICTION AND PRESSURE

Purpose: To determine why a spacecraft will be heated as it falls through the atmosphere

Concept to be developed: As a spacecraft enters the dense layers of the atmosphere, friction and compression will cause its temperature to increase tremendously.

Materials needed:

Block of wood
Hammer and nails
Sandpaper
Tire pump

INTRODUCTION: Ask the children, "What will the spacecraft encounter as it nears the Earth?" Explain to them that at about 100 miles, the spacecraft will begin to collide with an increasing number of air molecules. As the spacecraft gets closer to the Earth, the atmosphere becomes more dense. Elicit from the children their ideas as to the effect these collisions will have on the spacecraft. The following Activities will illustrate very simply some of the conditions a spacecraft would meet upon entering the dense layers of the atmosphere.

Have a child pound a nail into a block of wood, then feel the nailhead. How does it feel? *(It should feel warm.)* Likewise, as the spacecraft collides with air molecules, the surface of the vehicle will get warm.

Ask the children to rub two surfaces together, such as their hands, a block of wood and a block of sandpaper, etc. What is the effect? *(They become warm.)* Why do the surfaces become heated? *(Because of friction.)*

Pump a tire pump rapidly. Have the children feel the bottom of the cylinder. How does it feel? *(It should feel hot.)* What effect does compressing air have on its temperature? *(It increases the temperature.)*

Discuss meteors, or shooting stars. What are they? Where do they come from? Why do they flare rapidly across the night sky? Why don't many more of them strike the Earth? *(Most meteors are completely burned or vaporized before they get within 50 miles of the Earth. Their great speed sets up friction that heats them beyond their melting point.)* How is a space capsule like a meteor? How can it enter the atmosphere without being burned up, as a meteor is?

Explain that even as airplanes fly through the air, their surface temperature increases. At the speed of sound (700 miles per hour) the temperature increases by about 95° Fahrenheit. The X-15, an experimental rocket plane, has reached a surface temperature of about 1,200° Fahrenheit. Discuss with the children what they think will happen to the spacecraft as it enters the atmosphere at 17,000 miles per hour and at 25,000 miles per hour. At 17,000 miles per hour the spacecraft may reach a surface temperature of 3,000° Fahrenheit. At 25,000 miles per hour it may reach a temperature of 7,000° to 10,000° Fahrenheit.

Encourage the children to suggest ideas as to how this tremendous heat might be overcome. How can a spacecraft withstand such high temperatures without disintegrating or melting? How can man survive such temperatures?

The children will no doubt deduce that one way is to construct the spacecraft out of special materials. Can the children think of certain materials that withstand high temperatures? Encourage them to search in the kitchens of their homes to find materials used at high temperatures. Have them make a list of materials found, such as Pyrex, ceramics, aluminum, iron, Pyroceram. They should try to find out the temperatures at which these substances melt.

Learnings: Friction and the compression of air tend to increase the temperature. The entry surface of a spacecraft will be heated tremendously by friction and air resistance.

ACTIVITY 75 (x,y,z)

DESIGNING RE-ENTRY SHAPES

Purpose: To show that the re-entry craft can be designed to reduce pressure and friction

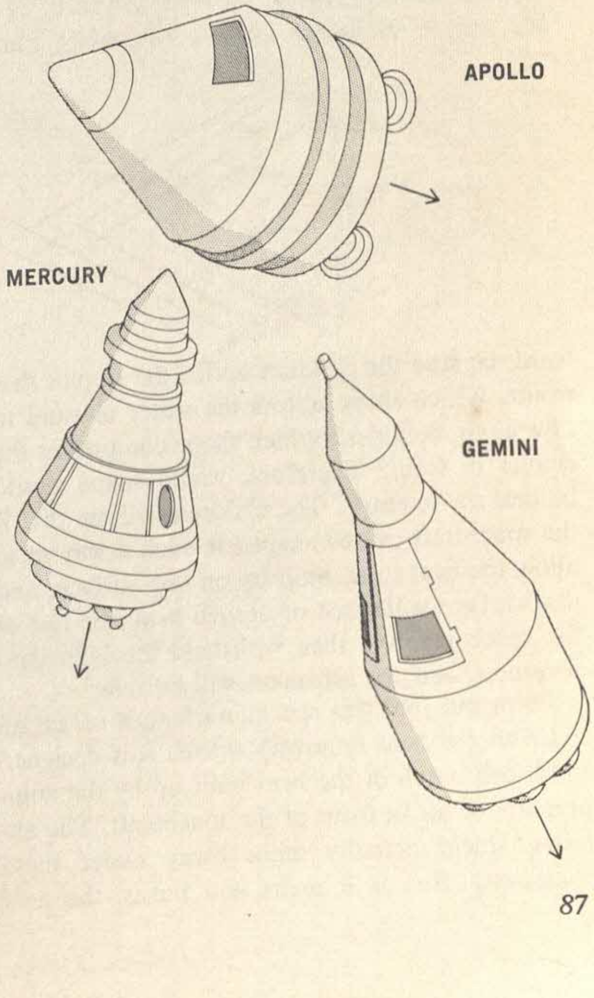
Concept to be developed: The shape of the re-entry craft can reduce the effects of friction and air resistance on the entry surface.

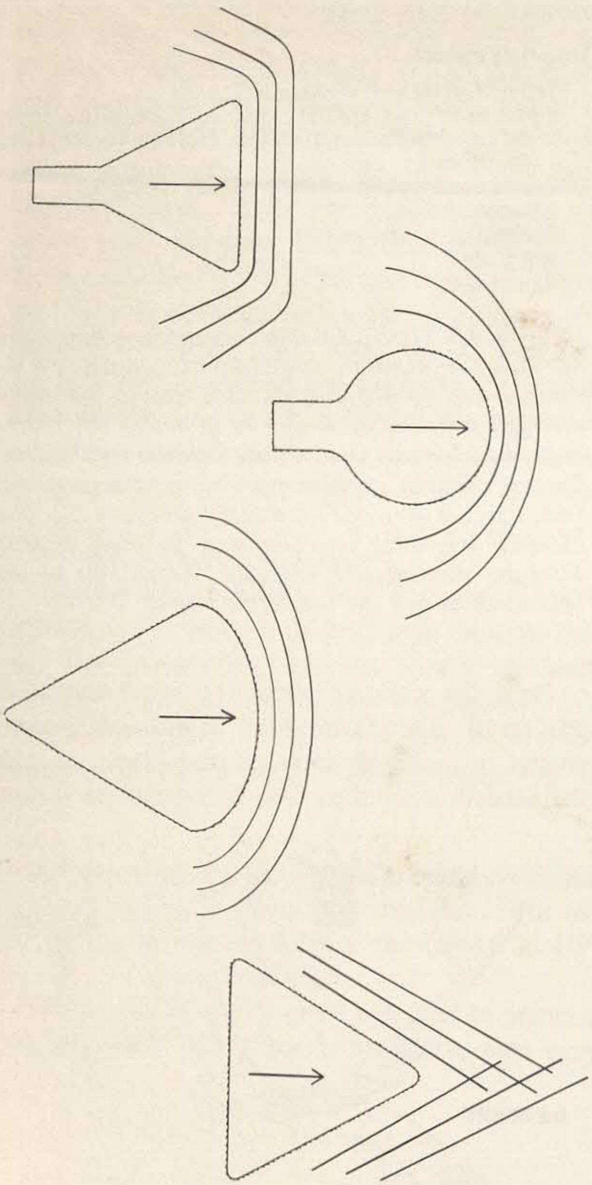
Materials needed:

- Balsa or other soft wood
- Items of various shapes, such as light bulbs, toys, catsup bottles, and coffee carafes, to serve as spacecraft
- 2 pyrex test tubes, nursing bottles, or flasks
- 2 thermometers
- Paraffin or candle wax
- Hot plate
- Pan of water

INTRODUCTION: Ask the children how they think the high temperatures caused by friction and air resistance can be coped with. One way to withstand the high temperature might be to design the spacecraft in such a way as to reduce pressure and friction. Let the children examine pictures of various spacecraft that are designed to return from space. Can the children recognize any similarity in their shapes? Why are they shaped this way? Which side of the spacecraft enters the atmosphere first? Why?

Help the children model various shapes of spacecraft. Let them float objects of various shapes in a tub of water or push them through the sand in a sandbox. As the objects move for-

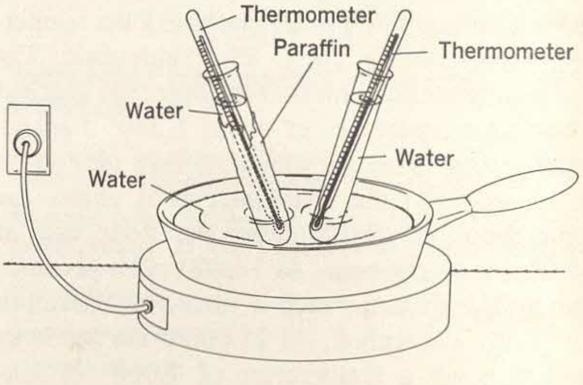




ward, be sure the children notice the ripples that result. Which shape allows the water or sand to flow along the sides? Which shape compresses the ripples in front? Therefore, which shape would be best for re-entry? The children will see that if the spacecraft can be shaped in such a way as to allow the heat to be built up on one surface, and that surface will resist or absorb heat, the rest of the spacecraft will then withstand the high temperatures, and the astronaut will be safe.

Point out that this special surface is called an *ablation* (or heat removal) *shield*. It is designed to absorb much of the heat built up by the compression of air in front of the spacecraft. The ablation shield actually melts away under these conditions. But as it melts and burns, the heat is carried away with it—away from the man in the space capsule. The children can understand in the following way how this works.

Have the children melt some paraffin or candle wax and dip one test tube, nursing bottle, or flask into the wax repeatedly, until a thick coat covers the outside of the container. Place a thermometer in the coated container and one in the plain container, and add equal amounts of water to each. Place each container in a pan of water and heat. Observe the relative changes in temperature inside the two containers as they are heated. *(The container coated with wax should remain cooler as the wax melts away.)* In the same way, the spacecraft will remain cooler as the ablation material melts away. Let the children find the ablation shield in pictures of space capsules. What would happen to the capsule if the ablation shield did not enter the atmosphere first?



Learnings: The re-entry vehicle can be designed in such a way as to reduce the effects of pressure and friction by using an ablation shield, which reduces the heat on the surface of the re-entry vehicle by melting away.

ACTIVITY 76 (x,y,z)

SLOWING THE SPACECRAFT

Purpose: To demonstrate the many ways in which the speed of the re-entry vehicle can be reduced

Concept to be developed: The re-entry vehicle must be slowed down in such a way as to overcome both the heating caused by friction and air resistance and the **G**–forces that result from too rapid a slowing down.

Materials needed:

Large piece of poster paper or tag board
Catsup bottle or similarly shaped object
Pieces of heavy bond paper

Cloth or tissue paper
String
Weights
Deep tub of water
Hammer and stakes

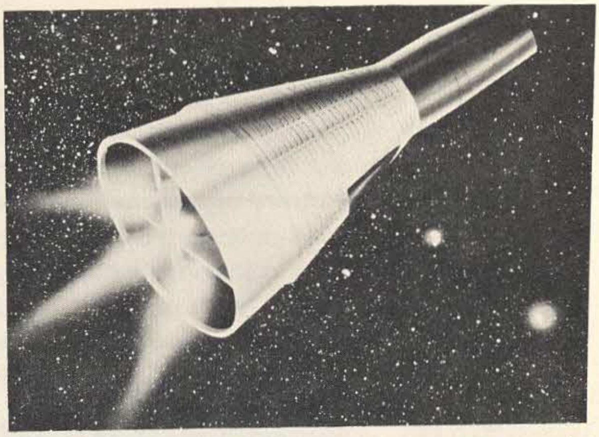
INTRODUCTION: Perhaps some children will suggest that another way to control temperature is to reduce speed. The spacecraft's speed must also be reduced so that it may be able to withstand the G-forces of deceleration and impact. Encourage the children to suggest various ways this tremendous speed might be reduced. The following Activity demonstrates several methods by which re-entry vehicles can be slowed.

Drag Decay: The atmosphere helps reduce the space capsule's speed. This is called *drag decay.* To demonstrate the manner in which drag decay works, choose the two fastest runners in the class for a race. Pin a large sheet of paper on one child and then have them run the race. Is it more difficult for the child with the paper to run fast through the air with a large, flat surface in front of him? Why? *(Because of air resistance.)*

In the same way, the *shape* of the spacecraft will also tend to slow it down. To illustrate this, have a child drop the catsup bottle into the deep tub of water. He should drop it first with the pointed side (top) down, then with the flattened side (bottom) down. In which position does the object go deeper into the water? *(When the pointed side is down.)* Have the children observe how the object's speed slows as it passes into the water.

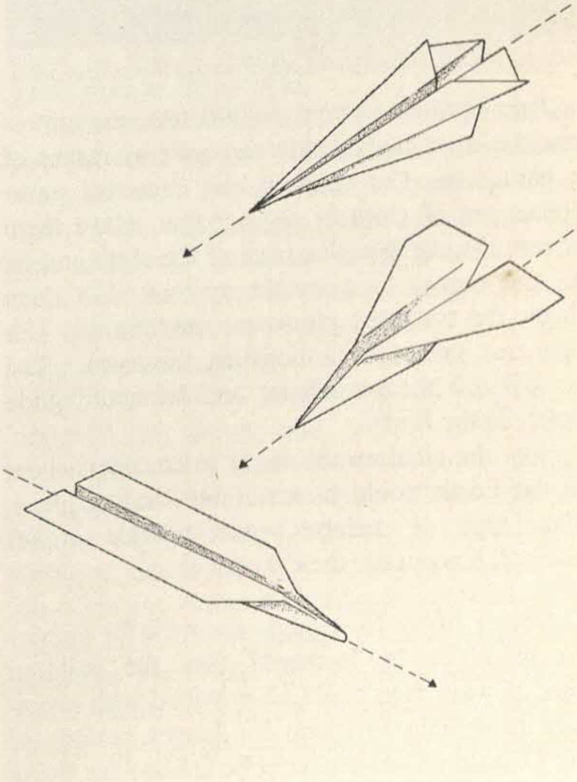
Another means of illustrating drag decay is to have the children pound wooden stakes of various shapes into the ground. Which shape is more difficult to pound, the pointed or the flattened? *(The flattened.)* From these experiences, can the children suggest how its shape might help slow the spacecraft?

Retrorockets: Another way to slow the spacecraft is to use *retrorockets.* Retrorockets are small but powerful rockets that are fired in the direction of movement. These serve to brake the spacecraft and slow it down. (Review the principle of action–reaction discussed in Chapter 4.) The retrorockets slow the spacecraft to below orbital velocity. What happens to the spacecraft when it is traveling slower than 17,500 miles per hour? *(It returns to Earth.)* Review the section on orbits in Chapter 4. What effect will such rapid deceleration have on man? *(The reduction of speed from 25,000 miles per hour to about 150 miles per hour in such a short time could be harmful to man.)*


Retrorockets are used to slow a re-entering space capsule.

Wings: Some spacecraft may be equipped with wings that will allow them to be maneuvered like a conventional airplane upon re-entry into the atmosphere. The wings will provide "lift" so that the descent toward Earth can be made slowly and accurately.

To demonstrate this, have the children construct gliders by folding sheets of paper. See



which glider sails the farthest. Let them experiment with many types of wings to see which provides the greatest lift.

Suggest that the children locate information about various winged re-entry spacecraft, such as the X-15. How are they constructed? How is it planned that they will re-enter the atmosphere and land? The children might also locate information about lifting bodies, such as the M–2 and M–3. How do they provide lift although they have no wings? How will they re-enter and land?

A Rogallo Wing, or paraglider, attached to a Mercury capsule.

Parachutes: At about 40,000 feet, the atmosphere can be used to slow the craft by means of a parachute. The children can construct parachutes out of cloth or tissue paper. Have them attach a string to each corner of the cloth and tie all the strings to a weight or rock. Let them throw the weighted parachute into the air. (Be sure that safety precautions are observed.) The air will fill the parachute, and it should glide slowly to the Earth.

Now the children are ready to consider where on the Earth would be a suitable landing place. What type of surface would provide a soft landing? Encourage their theories.

Extending Ideas: How might the need for numerous re-entries be lessened? Can the children think of ways man could be provided with necessities to remain in space for longer periods of time? Could an environment be created for living on the Moon? What would be needed? What materials are already there that man could utilize? How can man find out what materials are there?

Some children may wish to design a space station that would provide a base for refueling, rest, and research. How might the space station be designed to provide a comfortable environment?

Review with the children what they have learned so far. Point out that much research and experimentation must be done to solve the problems of re-entry. Returning man safely from space is dependent on his ability to slow, maneuver, and control the spacecraft through the barriers of heat and atmosphere.

Learning: Drag decay, retrorockets, wings, and parachutes are some of the means used to slow re-entry vehicles.

Summing Up Ideas: In this section, the children were introduced to some of the problems man faces in returning from space and some of the preventive means he has formulated. The children learned of the acceleration of free-falling objects caused by gravitational attraction and how this causes the re-entry vehicle to reach tremendous speeds. They learned of the heat that will result from friction and air resistance. They saw that the shape of the re-entry vehicle can be designed to lessen friction and air resistance and that ablation shields can be used to dissipate some of the heat. In addition, they saw some of the means—such as drag decay, retrorockets, wings, and parachutes—that can be used to slow the re-entry vehicle within the Earth's atmosphere.

WHAT CAN MAN DERIVE FROM SPACE EXPLORATION?

Discuss with the class why they think men climb Mt. Everest. Why did men set sail in tiny ships toward unknown seas? Why has man been eager to escape his Earth-bound home for thousands of years? Why do men dream and wonder and aspire? Perhaps the children will be able to understand that it is part of human nature to want to acquire and use knowledge. One basic difference between man and other animals is man's ability to gather, store, and apply knowledge by using his intellect.

Have the children collect information about the great men of history who have pushed back the frontiers of knowledge: ancient Chinese, Romans, Greeks, Arabs; Galileo, Da Vinci, Newton, Faraday, Einstein, and others.

ACTIVITY 77 (x,y,z)

LOOKING INTO SPACE THROUGH THE ATMOSPHERE

Purpose: To illustrate one of the reasons why we explore space

Concept to be developed: The atmosphere obstructs man's view of objects in space.

Materials needed:

Jar of water
Chalkboard erasers
Gauze, sheer stockings, or waxed paper

INTRODUCTION: Ask the children, "Would you like to go into space? Why?" Encourage their free answers and reasons. Then point out that if man is to find answers to his constant questions about the nature and origin of the universe, he must go beyond his Earth-bound home. Introduce to the children the idea that conditions on Earth make it impossible fully to study the universe. The following Activity will show them how living in the Earth's atmosphere gets in man's way of understanding objects in space.

Have the children look at the shimmering air over automobile hoods or radiators. This can best be noticed on a hot day when cars are parked in the sunlight. They should also look at various other objects through the shimmering air. Can these be seen clearly? Can the children speculate as to why the stars appear to twinkle? *(The atmosphere is in motion, and this disrupts man's vision.)*

Suggest that they look at objects through a tank or jar of water. Stir the water. How does this affect the image of the object?

Next, darken a room by drawing the shades. Allow only small shafts of light to come through. Have the children notice the movements of dust particles in the beams of sunlight. What does this show them about the atmosphere?

Have a child clap two chalkboard erasers together to produce a cloud of dust. Then have another child hold various objects in the dust. The children should try looking through this cloud at objects across the room to see how it affects visibility.

Suggest that the children also look at an electric light near the ceiling of a room. They should look at the light again through a piece of gauze, sheer stocking, or waxed paper. How does it appear? *(Less bright.)* Explain that, similarly, in space the Sun would seem brighter and clearer than it does when seen from Earth. This is because air acts in somewhat the same way as the gauze does to distort light.

Some children may ask: How will the sky appear in outer space? *(It will be black because there are very few particles in space to reflect light.)* How will the Sun, stars, and planets appear in space? Could man get a "better" look at them from the Moon as a space station than from his Earth observatory? *(Yes.)* Why? *(Probably there is no atmosphere on the Moon.)*

As the children know, some spacecraft are designed to gather and observe data about the nature of the Earth, Sun, and stars. Suggest that they collect information about the Orbiting Astronomical Observatory (OAO), the Orbiting Geophysical Observatory (OGO), and the Orbiting Solar Observatory (OSO). They should add this information to their space exploration log. What would the children like to know about conditions in space? Could they design spacecraft equipment to gather their data?

Learning: The atmosphere surrounding the earth hampers man's ability to observe the universe.

ACTIVITY 78 (x,y,z)

KEEPING A SPACE–APPLICATIONS LOG

Purpose: To illustrate the vast number of uses that space exploration serves

Concept to be developed: Space exploration serves man in a large number of ways.

Materials needed:

Large sheet of chart paper

INTRODUCTION: Besides finding many answers to age-old questions, bring out that we want to explore space so that we can apply the knowledge gained for the benefit of everyone.

Besides keeping a space exploration log (as in Activity 41), suggest that the children also keep a record of space vehicles that put to use our scientific knowledge to make our world a better, safer, more interesting place to live in.

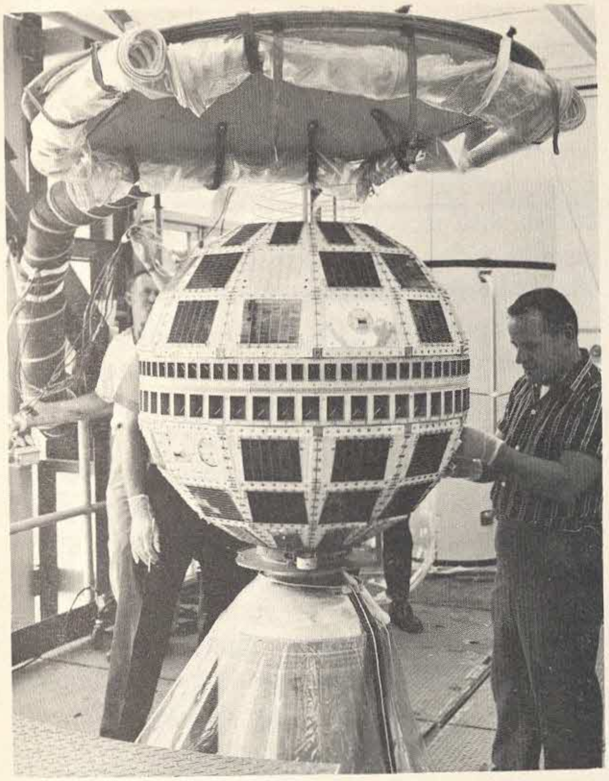
Can the children think of and detect some real problems and projects on Earth that might be solved and developed with our knowledge about space? Do they have some ideas about how a spacecraft may be designed to help solve such problems and serve man in other ways? For example, control of the weather, elimination of fog for safer air transportation, increasing communications, participating in international educational programs and cultural events throughout the world, international storehouse of information and knowledge, and libraries or computers in space. Are there in space some resources, such as energy sources, minerals, and food, that man could use?

Extending Ideas: Explain to the children that, besides the applications of space to the benefit of mankind, there are many by-products of the space age that man is finding useful. Suggest that some children may do research to discover and identify useful products in their community that are results of space-age technology. For example, how have hospitals benefited from space-age technology in the discovery of new medicines, methods, and equipment? What new products in the home are making life safer, more interesting, or easier because of space-age discoveries? How is industry being affected through space-age machinery, equipment, and processes?

Mention to them also that many new careers and professions have been created through space exploration. The children might discover these

SPACE APPLICATIONS LOG

Name of spacecraft	Date of launch	Purpose	Description	Benefit to mankind
Echo I Echo II	Aug. 20, 1960 Jan. 25, 1964	Communications satellite to reflect radio and telegraph messages from one point on Earth to another	100-foot-diameter balloon made of mylar plastic coated with an aluminum film	Beginning of an international communications network that will save money and facilitate communications between nations of the Earth
Tiros I Tiros II Tiros III Tiros IV Tiros V Tiros VI Tiros VII	Apr. 1, 1960 Nov. 23, 1960 July 12, 1961 Feb. 8, 1962 June 19, 1962 Sept. 18, 1962 June 19, 1963	Weather satellite to take pictures of the Earth's cloud cover for weather prediction	Has TV cameras to take cloud pictures and infrared sensors to measure heat	Increases man's ability to observe, predict, and ultimately to control the weather. This was previously impossible over large areas of the Earth.
Relay I	Dec. 13, 1962	Communications	Relays radio signals	
Syncom I Syncom II	Feb. 14, 1963 July 26, 1963	Communications	Orbited at 22,300 miles to form a "stationary" satellite over the Atlantic Ocean	
Telstar I Telstar II	July 10, 1962 May 7, 1963	Communications	Relays TV signals	Experimental TV exchange system
OSO-1	March 7, 1962	Solar observatory	Boxlike shape	Astronomical research



TELSTAR is a communications satellite.

by surveying the professions, jobs, and careers of their parents and the parents of other children. How many of them are working in a space-related field? Survey their parents' occupations ten years ago; five years ago. How has space exploration changed their occupations in that amount of time? Invite someone who works in a space-related field to discuss this with the class. Locate the businesses and industries in the community that are related to space exploration. What do they produce? Where do they get their raw materials? Where are their finished products delivered? How are they transported?

Suggest that the class take a study trip to a nearby space-related industry to interview some of the workers. Help the children to learn more about the products developed and materials used.

Learnings: The space age has affected our lives in many ways. The practical applications of satellites are proving very helpful to man.

ACTIVITY 79 (x,y,z)

IDENTIFYING NATIONS ENGAGED IN SPACE EXPLORATION

Purpose: To show that the exploration of space is a cooperative effort

Concept to be developed: A great many nations are involved in the exploration of space, some independently and some in cooperation with others.

Materials needed:

World map
Chart paper

INTRODUCTION: The two pioneers in space exploration, of course, were the Soviet Union (which, in 1957, orbited the first two Earth satellites) and the United States (which, in 1958, orbited the third Earth satellite). However, a number of other nations also have advanced space programs under way. In the following Activity, the children should be encouraged to learn of the scientific cooperation between nations and the work of nations other than the United States and the Soviet Union in furthering the space age.

Have one group of children do research and report to the rest of the class on the first two satellites to be launched under international cooperation agreements, Ariel and Alouette.

A second group might report on ELDO (European Launcher Development Organization), a cooperative space effort between the United Kingdom, France, Germany, Italy, Australia, Belgium and the Netherlands.

A third group may make a map to show the locations of the many nations that are engaged in space exploration and list their accomplishments to date.

Pose the following questions to the children as subjects for individual or group reports and panel discussions: How has the United States helped disseminate scientific knowledge? How has the United States assisted other nations in their programs of space exploration? How has the United States cooperated on joint projects of weather prediction, navigation, and communications? Which countries have launched scientific satellites in cooperation with the United States? Suggest that as a result of all the reports and discussion on these questions, the class might develop an international space exploration log. This log should be kept up to date as further space developments occur.

Learnings: Many nations are engaged in space exploration. International scientific cooperation has been furthered by joint launching efforts and international use of navigation, communication, and weather satellites.

ACTIVITY 80 (y,z)

DEVELOPING A SPACE EXPLORATION TIME LINE

Purpose: To discuss the rapid advances being made in science and technology

Concept to be developed: A great deal of technological progress has been made since the dawn of the space age.

Materials needed:

Chart paper, butcher paper, or wire
Pictures, models, etc.

INTRODUCTION: Review with the children their previous discussions about man, and how throughout the centuries he has thought of escaping the Earth. Only recently, however, has he had the technological know-how to accomplish this. Have the children collect pictures, read about, and discuss the feasibility of the ideas of such men as H. G. Wells, Jules Verne, and others. Do many children enjoy science fiction? Point out that these men were science fiction writers. Which of their ideas have come to pass? Discuss the ideas found in present-day science fiction. How feasible are they? Why? Help the children write their own science fiction stories, using their knowledge as the basis. A historical perspective may help the children perceive man's desire to discover, explore, and exploit his environment. To achieve this perspective, the children may construct a time line, as in the following Activity.

Suggest that the children develop a time line showing historic scientific events that have contributed to man's ability to explore space further. Can the children see how the events of history have intermingled with man's scientific knowledge and progress? What scientific progress took place during the Stone Age? What scientific progress occurred during the Golden Age of the Greeks? What progress was made during the Dark Ages? The Renaissance? The Industrial Revolution? The children can observe the effects of the Industrial Revolution on their lives today. How are the effects of the space age being realized today? How will they affect our way of living in the future?

Extending Ideas: Perhaps you may be able to establish with the children the idea that man is a creative being. His deepest satisfaction comes when he enjoys a feeling of creative accomplishment. Discuss with the children how they feel when they have written a poem, painted a picture, or constructed something. Mention that similarly, throughout history, man has had a desire to create. Some of the children may be able to appreciate the idea that the creativity, ingenuity, and productiveness of the past allows us to dream of the future. Dr. Robert Goddard has said, "The dream of yesterday is the hope of today and the reality of tomorrow." It might be useful to put this quotation on the board and see what the children think it means. A most rewarding discussion might ensue.

Learnings: There has been a great deal of progress in science throughout the ages. This progress always has been influenced by political and historical events, and by man's own capacity to think, reason, and dream.

Summing Up Ideas: In this section, the children were introduced to some of the progress of the space age. They learned of the varied uses to which satellites are being put and of the international cooperation that has resulted from the desire of many nations to participate in the exploration of space. In addition, they learned of some of the benefits that man hopes ultimately to derive from his space exploration.

IMPORTANT IDEAS IN THIS CHAPTER

For the kindergarten, primary, and intermediate grade children, the ideas with the most meaning and application are:

- Man must take the necessities of life into space with him.
- Man needs oxygen to survive; when he ventures into space, he must carry his oxygen with him.
- Friction and the compression of air tend to increase the temperature of a body in free fall.
- An ablation shield helps dissipate the heat generated by a re-entry vehicle returning to the Earth.
- Drag decay, retrorockets, wings, and parachutes are some of the means to slow re-entry vehicles.
- The Earth's atmosphere makes it difficult to see things in space clearly.

In the intermediate and upper grades, the children should be led to develop concepts that are more complex and quantitative:

- Man requires an air pressure of about 15 pounds per square inch in order to survive. To maintain this pressure in space, he must wear a pressurized space suit or remain in a pressurized capsule.
- Man, while in space, must be protected from radiation and variations in temperature.
- Weightlessness occurs when the spacecraft is either beyond the pull of the Earth's gravity or when the Earth's gravity is counterbalanced by the rocket's forward thrust.
- A freely falling body accelerates at the rate of 32 feet per second each second.

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BIBLIOGRAPHY

Goodwin, Harold Leland. *Space: Frontier Unlimited.* Princeton, N. J.: D. Van Nostrand Company, Inc., 1962. An excellent introduction to the entire scope of the space program, including space science, practical and political uses of space, military considerations, and social prospects of the space program.

Hagerty, James, and Woodburn, John H. *Spacecraft* (Vista of Science Series). New York: Scholastic Magazines, Inc. and National Science Teachers Association, 1961. A well-written book for junior and senior high school students which discusses America's achievements in space and the U.S. program for space exploration over the next ten years.

Hynek, J. Allen, and Anderson, Norman D. *Challenge of the Universe* (Vista of Science Series). New York: McGraw-Hill, Inc., 1962. This book, a joint project of the National Science Teachers Association and the National Aeronautics and Space Administration, gives a fascinating account of astrophysics and celestial mechanics. Projects and experiments are included.

National Aeronautics and Space Administration. *Space, The New Frontier.* Washington, D.C.: U.S. Government Printing Office, 1959. An excellent fully illustrated introduction to space exploration.

Schneider, Leo. *Space in Your Future.* New York: Harcourt, Brace & World, Inc., 1961. A clear and concise description of our physical world, the universe around us, and the strides we are making in space.

Zim, Herbert S. *The Universe.* New York: William Morrow and Company, Inc., 1961. A child's history of our knowledge of the universe.

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